WATER

QUALITY OF

THE LOWER
MISSOURI
RIVER

WATER QUALITY OF THE LOWER MISSOURI RIVER, GAVINS POINT DAM TO MOUTH

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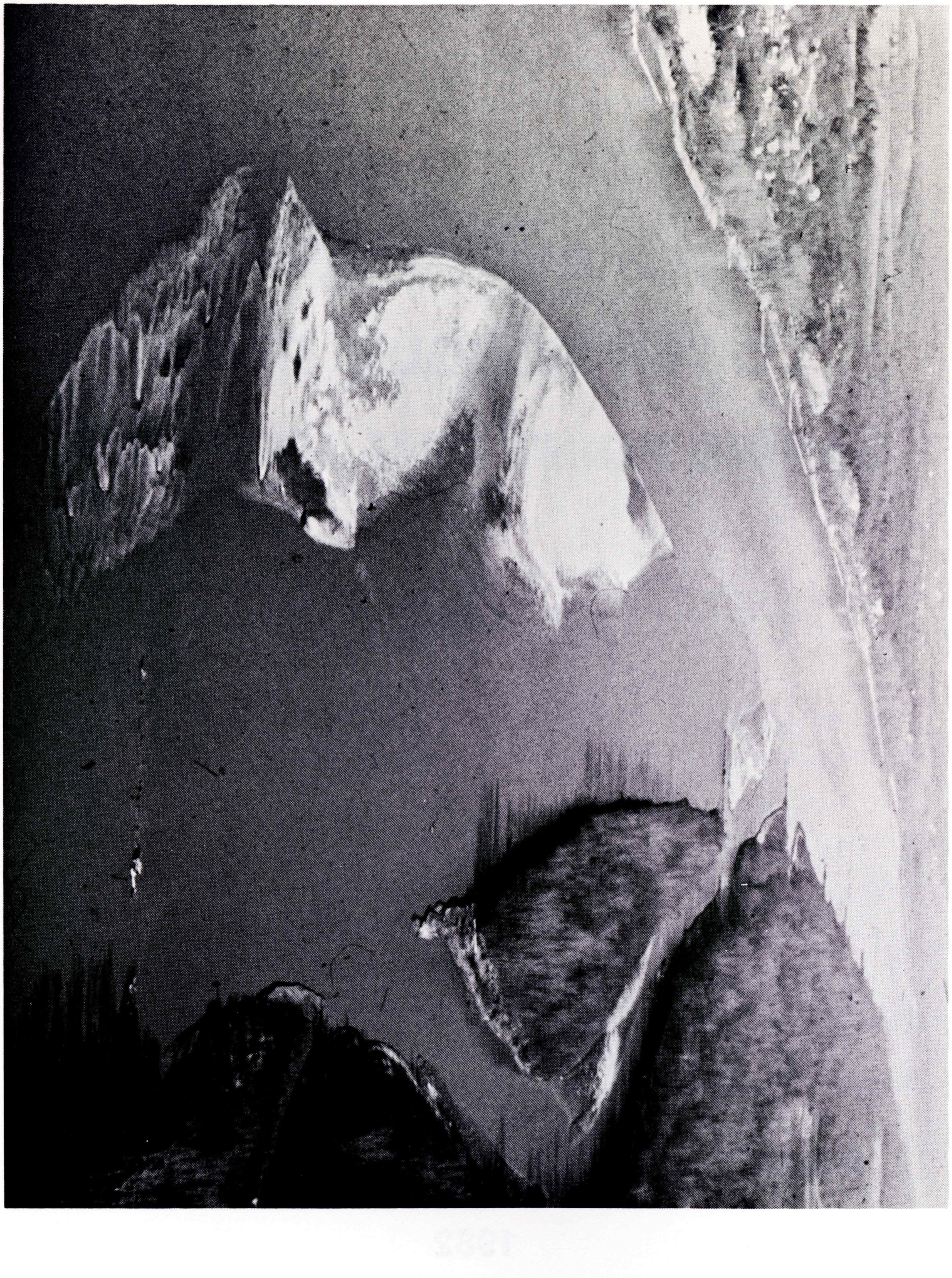
1982



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ERRATA

Page 1 Second column, fourth paragraph, second sentence, "considerable" should read "considerably".

Page 8 Second column, first paragraph, last sentence, "increase coliform" should read "increased coliform".

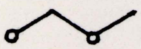
Page 9 Table 1, last two column headings should read

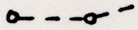
"

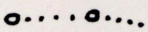
Average Annual Sediment Load	
Prior to 1953	After 1955

"

Page 10 Key to Figure 5 is missing. Key should read

 Sioux City

 Omaha

 Hermann, Mo.

Page 11 First column, fourth paragraph, last sentence, "int he" should read "in the"

page 11 Second column, third paragraph, fourth sentence should read "...from organic N to ammonia within the plant." Sixth sentence should begin, "This oxidized form is..."

Page 12 Figure 8. The symbol NH_4^+ N applies to the solid black area of the figure.

Page 12 Figure 10. The units on the Y axis of the graph are missing. The units should be "Total N, mg/l"

Page 13 First column, second paragraph, last sentence, "increases" should be "increasing".

Page 17 Second column, first paragraph, last sentence should read, "The continued occurrence of DDT and dieldrin is expected to become a less important problem..."

Page 18 Table 9, third column, "rain-effected" should read "rain affected".

CHAPTER 1
A HISTORY OF WATER QUALITY PROBLEMS ON THE LOWER MISSOURI RIVER

TYPHOID: AN EARLY PROBLEM

The year 1890 is generally regarded as marking the end of the frontier. Just a few years after the pioneers had found the limits of the vast, unpopulated lands of the American west, the people living along the Missouri River found limits on how much sewage they could safety dump into the river.

A sharp increase in typhoid deaths occurred among the towns along the Lower Missouri River during the winter of 1909-1910. This increased death rate prompted state health officials to request a study of the river and its relationship to the incidence of typhoid. This study was entitled, "Sewage Pollution of Interstate and International Waters -- With Special Reference to the Spread of Typhoid. VI The Missouri River from Sioux City to Its Mouth" (U.S. Public Health Service, 1913). The report presented data on typhoid death rates for many towns along the lower Missouri including Sioux City, Omaha, Council Bluffs, St. Joseph, and the two Kansas Cities. The report concluded that sewage pollution in the Missouri was at least partially responsible for the increase in typhoid deaths. The report was also instrumental in pointing out the need for effective disinfection of drinking water supplies. Although Kansas City, Kansas, and Kansas City, Missouri, withdrew drinking water from the same approximate location, Kansas City, Missouri, had a much lower typhoid death rate. The report noted that Kansas City, Missouri, treated river water with hypochlorite of lime, while Kansas City, Kansas, practiced disinfection only part of the time and that the method of mixing the hypochlorite of lime, when used, was not effective.

RISING BACTERIAL CONTAMINATION, LOW DISSOLVED OXYGEN, GREASE

For the next forty years the major water quality concern continued to be the level of bacterial contamination of the Missouri and the river's ability to provide safe drinking water. Although disinfection by chlorination became standard practice, the degree of bacterial contamination of the raw water supplies dictated the degree of disinfection treatment required. In 1946, the Public Health Service published recommendations for water treatment (USPHS, 1946). In that publication, the Public Health Service recognized four levels of coliform bacterial contamination requiring more complex and costly treatment to insure the complete disinfection of the water.

Certain public water suppliers drawing from the Lower Missouri had been making regular determinations of coliform concentrations on raw river water. In comparing the levels of coliform in the river to the standards published by the Public Health Service, it was immediately apparent that most of the Lower Missouri was in the category of highest contamination. This, in turn, led to concern over the adequacy of existing disinfection procedures being used by supplies drawn from the Missouri.

This concern resulted in a second study, performed jointly by the Public Health Service and the state health agencies of Iowa, Missouri, Kansas, Nebraska, Minnesota and South Dakota in 1950 (USPHS et al, 1952). This report documented that there had been substantial increases in the average number of bacteria in the river since the 1913 report. Records kept by the Kansas City, Kansas, water supplier showed a steady increase in average annual coliform concentration in the river between 1922 and 1951.

This increase in bacterial contamination was certainly understandable. The population had grown considerable since 1910 as had the meat packing industry and stockyards, while there remained very little treatment of wastes. The 1952 report contained pictures of municipal, meatpacking and stockyard wastes flowing untreated into the Missouri or nearby tributaries. Collection of samples in 1950 at many places on the river showed that, indeed, coliform bacterial levels in the Missouri were always highest immediately below large towns or stockyards. Levels gradually dropped but were still high by the time the water flowed by the next large town which withdrew water for public consumption.

A second water quality problem, low dissolved oxygen in the river water, was also noted in this study. During the summer, the acceptable minimum of five milligrams per liter (mg/l) was just being

maintained at Omaha, while below Kansas City, concentrations as low as 3.8 mg/l were recorded at Lexington and 2.8 mg/l at Boonville (40 and 150 miles below Kansas City, respectively). These low levels threatened the life and well being of many species of fish in the Missouri and also their ability to reproduce.

Additional sampling of coliform bacteria throughout 1955 and 1956 at several locations on the river confirmed the nature and magnitude of the bacterial contamination problem presented in the 1952 report (USPHS et al, 1956). This cooperative monitoring effort by the Public Health Service and the state health agencies of Nebraska, Iowa, Kansas and Missouri concluded that, indeed, the major part of the contaminants observed at the water intake of any city came from the first large wastewater source upstream. Observations of coliform die-off trends indicated the larger the discharge and the warmer the weather, the longer the bacteria survived in the river. Invariably, the highest levels of bacterial contamination occurred in either the summer or fall.

Another study of bacterial contamination concentrating on the segment of the river from Yankton, South Dakota, to Omaha followed in 1958 (Kittrell, 1958). It reported levels of coliform bacteria similar to those in the 1952 and 1956 reports for that segment of the river. Thirty-five of thirty-nine monthly averages exceeded the suggested level for bacterial quality of a drinking water supply source for the type of treatment provided at Omaha. The report also pointed out the hazards of bacterial contamination to river recreationists.

In addition to bacterial contamination, the report mentioned the problem of grease which, during periods of rapid water temperature decrease, tended to coat and clog intake screens at the Omaha water treatment plant.

BEGINNING THE POINT SOURCE CLEANUP, INDICATIONS OF THE NONPOINT SOURCE PROBLEM

At that time, the federal government expanded its role on the Lower Missouri River to include enforcement of federal clean water laws. This dimension of federal involvement was made possible by Public Law 84-660, passed in 1956, which extended and strengthened federal water pollution control activities, particularly with respect to enforcement actions against pollution of interstate waters. Federal actions began with a series of enforcement conferences between federal, state and city officials in 1957 and 1958. These conferences, held for the purpose of describing pollution problems and possible solutions, resulted in a timetable for awarding contracts for wastewater treatment works for each of the major metropolitan areas.

Following the initial enforcement conferences, progress by cities was slow; but after meetings and one federal court action, construction of facilities to reduce point source pollution began in the 1960's.

The problem of nonpoint pollution sources was highlighted by a fish kill in the river in the Kansas City area in May, 1964. Caused by widespread heavy thunderstorms, large amounts of organic materials were washed into the river or resuspended from river bottom deposits as river stages and flow velocities increased. The oxygen demanding wastes in the river at the time were estimated to equal the discharge from fifty million people. Dissolved oxygen levels as low as 1.5 mg/l were measured below Kansas City a few days after the fish kill, and speculation included the possibility that a portion of the river had been completely deoxygenated. Occurring at a time when local, state and federal governments were wrestling with the problems of point source discharges, this incident revealed that serious water pollution control efforts on the Missouri would require more than the construction and operation of facilites to treat municipal and industrial wastes.

THE MAIN STEM RESERVOIR SYSTEM AND ITS IMPACT ON WATER QUALITY

The mid-sixties also marked the completion of the main stem reservoir system as we know it today. The Fort Peck Dam in Montana was completed in 1937 and was filled by 1942. The other five dams, Garrison (N. Dakota), Oahe, Big Bend and Ft. Randall, (S. Dakota) and Gavins Point Dam (S. Dakota-Nebraska border), were completed between 1953 and 1964.

The water quality effects of the impoundment of the Middle Missouri were addressed by the Public Health Service, with water quality data being collected between 1952 and 1957 (Neel, 1963). Sample sites included the Lower Missouri down to Omaha.

The most obvious and furthest-reaching impact of those six impoundments upon the Lower Missouri is the reduction in suspended sediment concentrations. This reduction is greatest just below these impoundments, but is still significant at the mouth of the Missouri over 800 miles downstream. For example, annual suspended sediment loads at Yankton, South Dakota, immediately below Gavins Point Dam, have been reduced to one percent of what they were prior to construction of the five lower reservoirs. At Omaha, approximately 200 miles below Gavins Point, suspended sediment loads are only 14 percent of levels prior to impoundment and at Hermann, Missouri, over 700 miles below Gavins Point, the present suspended sediment load is about one-third of what it was prior to impoundment.

A second change caused by the main stem reservoirs is an increase in the phytoplankton discharged to the Lower Missouri. The anticipation of increased concentrations of phytoplankton and

accompanying taste and odor problems for water supplies resulted in the 1952-57 work. The study found that taste and odor problems almost always occurred when there were large amounts of algae in the river, particularly when the algal populations were declining, indicating some chemical(s) associated with decomposition of algae was involved. Since the greatest algal densities in the Lower Missouri generally are in the Yankton and Sioux City area, potential taste and odor problems have been more frequent there. The report found algal densities further downstream at Omaha only 30 percent of those at Yankton, and Omaha apparently had fewer occasions when there were taste and odor problems. Where water suppliers were forewarned of high algal concentrations, they were able to successfully treat taste and odor problems with chlorination and activated carbon.

Two other water quality effects of impoundment were of minor importance to the Lower Missouri. Supersaturation of dissolved oxygen caused by photosynthesis in the reservoirs and physical entrapment as water passed through the Gavins Point Dam raised dissolved oxygen (DO) levels in the Missouri for a number of miles below the dam. However, since this effect was only important above Sioux City, it does nothing to mitigate low DO problems which have occurred exclusively below Sioux City. A second effect of the increased photosynthetic rates in the reservoirs is a slight (2-3%) reduction in alkalinity due to the precipitation of calcium carbonate. This has the effect of slightly reducing the hardness of the water.

Therefore, the major effects of impoundment have been to increase levels of phytoplankton and accentuate taste and odor problems in areas just below the reservoirs, as a trade-off for much lower levels of suspended solids throughout the lower river.

The very presence of the reservoir system, however, has other water quality implications. The ability to control flows in the Lower Missouri was a water quality management tool not overlooked by the Federal Water Pollution Control Administration (FWPCA). In 1969, that agency set minimum downstream requirements for water quality control (waste dilution and assimilation) and maintenance of the 5 mg/l DO standard for minimum releases from Gavins Point Dam. The Corps of Engineers also regulates warm weather flows from Gavins Point for commercial navigation. Since the flows necessary for navigation by commercial barge traffic are 10 and 3 1/2 times the FWCPA recommended flows at Sioux City and Kansas City respectively, the reservoir system, as operated, has minimized dissolved oxygen problems caused by low flows and lack of adequate waste dilution.

FURTHER POLLUTION STUDIES

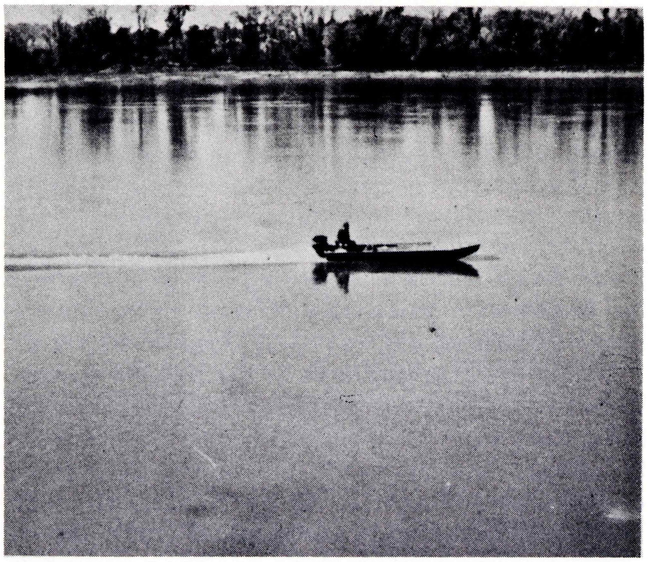
In the fall and winter of 1968-69, an extensive survey of the Lower Missouri was conducted by the Federal Water Quality Administration (Ballentine, 1970). Samples were taken at 56 locations between Yankton, S.D., and Hermann, Missouri. They found that coliform bacterial densities exceeded by several times the accepted criterion for sources for public water supply and for recreation. Other point source source problems included potentially toxic, concentrations of lead and cyanide in the area just below Sioux City and large amounts of grease and the presence of greaseballs floating on the surface below Omaha all the way to St. Joseph, Missouri.

During the last two days of the autumn survey, there were rains which caused a significant increase in discharge and provided an excellent opportunity to compare the effects of point source discharges and pollutants brought to the river by surface runoff. The report noted large increases in total coliform and in fecal coliform bacteria as flow increased in the river. Maximum total coliform counts were four times higher and fecal coliform counts 20 times higher during rain affected flows. Dissolved oxygen concentrations dropped in response to higher flows. These two days of sampling pointed out again that the most severe, albeit short term, water quality problems appeared to come from surface runoff.

WATER QUALITY STANDARDS ESTABLISHED

By 1970, it was certainly obvious to everyone that some sort of water pollution control plan was needed on the Missouri. The eleven largest water treatment plants on the river now supplied this water to over three million people. Something had to be done to reduce present levels of pollution and protect the river from the discharges accompanying future population and industrial growth.

The first step toward a management plan for water quality in the Lower Missouri was taken by the FWPCA. They required the states of Nebraska, Iowa, Kansas and Missouri to develop water quality criteria for the Lower Missouri. Developing criteria required public meetings to determine what the important uses of the river were and a set of standards to protect each of those uses. In 1968, the FWPCA had published such a set of standards entitled, "Water Quality Criteria." These standards were the result of work by a national advisory committee comprised of well known experts from many fields. By the summer of 1970, the federal government and the states of Iowa, Nebraska, Kansas and Missouri had reached basic agreement upon the level of water quality which should be maintained in the Lower Missouri River. There was some disagreement with certain proposed standards so, to more fully document the problem, the FWCPA undertook further water quality studies in 1969-1970. The study purpose was to determine how much of the pollution in the river could be controlled by point source waste treatment. The study included sampling from above Sioux City,



Iowa, to Waverly, Missouri, below Kansas City, and measured bacterial densities, looked for the presence of pathogenic organisms (e.g., *Salmonella* and enteric virus) and direct evidence of recent fecal contamination (e.g., the presence of a fecal sterol, coprastanol). The study also estimated the periphyton (attached algae) of the river bottom and the ability of river water to taint the taste of fish.

As in earlier studies, sharp increases in coliform bacteria (this time fecal as well as total coliform) were noted immediately below major cities. Samples of river water were also tested as a growth medium for bacteria and showed that the nutrients and organic material in the river were capable of sustaining bacterial populations for many days. The presence of enteric virus was found in many locations in the river and coprastanol was found at all sampling locations.

The study of fish flavor tainting did demonstrate that this problem is most apparent in the areas just below major waste discharges to the river. The affected areas were relatively short below Sioux City and Omaha (one and two and one-half miles, respectively) but was 22 miles in length below Kansas City.

The periphyton study resulted in highly variable densities of algae, protozoans, and fungi, which did not correlate with the location of major waste discharges to the river.

MUNICIPAL WASTEWATER TREATMENT

Since negotiations concerning the levels of wastewater treatment needed at cities along the Missouri have involved city, state and federal agencies and occasionally the federal courts, the construction of treatment plants has progressed at different rates in different cities. All major cities had primary wastewater treatment plants in operation during the 1960's. Several cities built secondary treatment plants during the 1970's. The present status of wastewater treatment of major dischargers along the Lower Missouri is as follows:

Secondary Treatment	Primary Only
Sioux City, IA	Omaha, NE
Iowa Beef Packers (Dakota City, NE)	Papillion Ck. (Omaha), Nebraska
Council Bluffs, IA	Kansas City, Kan.
Bellevue (Omaha), NE	Kansas City, MO
Nebraska City, NE	
St. Joseph, MO	
Leavenworth, Kan.	
Atchison, Kan.	
Jefferson City, MO	
Missouri R. Plant (St. Louis) MO	

DOES THE MISSOURI MEET EXISTING WATER QUALITY STANDARDS?

There have been two revisions of the states' water quality standards since the initial round of standards in 1968-1970. The federal "Clean Water Law" of 1972, PL 92-500, foresaw the dynamic nature of water pollution management due to the continual research and steady growth in our knowledge of problems and how to solve them. To insure that standards reflect the most current knowledge, the federal law requires that all states review their water quality standards every three years, and revise as necessary. The present standards for the states of Nebraska, Iowa, Kansas and Missouri were written in 1977. The states are now making their third revision of the original standards documents.

Four criteria are of particular interest to this discussion of the Missouri's water quality problems.

The first problem is the high level of fecal coliform bacteria. Although these bacteria are not pathogenic themselves, they are used as indicators of water-borne bacteria and viruses which can cause disease. The states of Nebraska and Iowa, in their water quality standards, have identified whole body water contact recreation (swimming and skiing) as a use to be protected in the Missouri where it borders those states. The standard of 200 bacteria/100 milliliters (ml) of water is almost always violated below Sioux City. It is interesting to note that there is no longer a bacterial standard for domestic water supply sources. All four states draw water supplies from the Missouri but have no bacterial standard for that use, reflecting the confidence in disinfection procedures now used at water companies.

All four states have a minimum dissolved oxygen standard of 5 mg/l to protect fish and other aquatic life. DO levels in the river occasionally drop below this level, usually in response to oxygen demanding materials washed into the river by surface runoff. Oxygen demanding wastes from point sources, although not important in large DO reductions, exert a constant demand and keep DO levels in the

river lower than they otherwise would be.

A third concern is high levels of sulfate. Kansas and Missouri have a secondary (aesthetic) drinking water standard for sulfate (SO_4^{2-}) of 250 mg/l. Sulfate concentrations in this part of the river average about 165 mg/l at St. Joseph and decline to about 130 mg/l at Hermann, Missouri, with maximum recorded levels of 240 mg/l at St. Joseph. Future uses of the Missouri may include the processing of western coal and increased irrigation of crops. Both these uses could result in return flows to the Missouri high in sulfates which, in turn, could raise the levels of sulfate in the river above the standard.

The fourth constituent of concern is mercury. Violations of the mercury standard occur primarily because the standards allow only extremely small amounts of mercury in the water, .0002 mg/l for Iowa and .00005 mg/l for Missouri. Such natural processes as weathering and soil erosion alone may provide enough mercury to streams to occasionally violate the standard. Additional sources of mercury would add to the magnitude and frequency of mercury violations. The Iowa standard was exceeded once for the twelve times samples were taken at Sioux City, once in seven times at Omaha, and once in nine times at Nebraska City, Nebraska, during sampling from 1977 and 1979. Missouri has a more stringent standard and has had more violations of that standard. Six of twenty analyses at St. Joseph (1975-1979) and twelve of thirty-four at Hermann (1971-1979) exceeded the mercury standard.

The emphasis on the Missouri's water quality problems has now shifted to toxic chemicals found in the river in small amounts. During the last 30-35 years there has been unprecedented growth in the chemical industry in both volume and kinds of chemicals made and used. USEPA presently lists 44,000 commercially used substances (Reif, 1981). Every year, many man-made chemicals never formed before on earth are produced and exposed to the environment. In many cases, their effect on the environment is unknown. USEPA has identified a list of 129 elements or compounds which they consider pollutants in water, even in very small concentrations. Sampling on the Lower Missouri River during the 1970's has revealed the presence of ten heavy metals, three pesticides and two volatile organics on the priority list. The Metropolitan Sewer District of St. Louis, during sampling in 1980 of influents at four wastewater treatment plants, detected the presence of 37 of the priority pollutants, including all 13 metals on the list, cyanide and 23 organic compounds, most of which were common industrial solvents (MSD, 1980).

Since removal of these pollutants requires special water treatment not regularly practiced at water treatment plants, the fact that several of these chemicals are known or suspected carcinogens causes concern.

A number of studies have attempted to correlate drinking water quality and cancer rates. This type of study is very difficult to do accurately because of the many variables that contribute to cancer other than water quality, such as air pollution and other types of environmental contamination, age, income, occupation, personal habits (e.g., smoking), population migration, inconsistencies in how coroners report cause of death, inaccurate diagnosis of disease and the difference between the incidence of cancer and cancer deaths (in many areas only the latter is available in records).

The first of such studies in Missouri (Cook and Watson, 1966) showed that the ratio of secondary cancers (a second cancer which is not connected to or caused by the first cancer) to primary cancers was highest in counties bordering the Missouri River. The results do not seem to implicate Missouri River water, however, since most of the counties were rural and only a very small percent of county residents used the river as a drinking water supply.

Page (1976) found statistically significant positive correlation between cancer death rates in Louisiana parishes and the percentage of the parish population using the Mississippi River as a drinking water supply. That study also found other factors such as population density and occupation were significantly correlated with cancer deaths.

A study of cancer mortality along the Mississippi and Missouri Rivers was conducted by Meinhardt (unpublished). This study compared cancer deaths in twenty counties drawing most of their water from the river to six counties along the river using little or no river water for drinking water supply. The study locations ranged from Louisiana to Minnesota on the Mississippi river and from St. Louis, Missouri to Montana on the Missouri River. Unlike the Louisiana study, no significant correlation between cancer deaths and the use of the rivers for drinking water supply was found. Neither was there a trend of increasing cancer deaths in the downstream direction. The study did show that cancer death rates can vary greatly at two nearby locations. A follow-up study by Marienfeld (1980) examined the causes for the greatly different cancer rates in St. Louis City and St. Louis County which use the same drinking water supply. Such variables as income, years of schooling, unskilled labor versus other occupations, and air pollution showed significant correlation with cancer death rate.

Therefore, there is no evidence at present which links the drinking of Missouri River water with cancer. Environmental factors in total are a major cause of cancer, but, in the majority of studies cited, drinking water was of such minor importance as a specific cause that its effect was undetectable.

Our ability to manage water quality to protect drinking water supplies from compounds which may be toxic in very small amounts is hindered by

several problems.

First, there are a very large number of different substances with which to contend. As mentioned earlier, USEPA now lists some 44,000 of which only 7,000 have been tested for carcinogenicity. Secondly, many of these pollutants are costly and difficult to measure, a problem which is greatly compounded by the large number of different pollutants. Thirdly, and of most concern, for most of these pollutants we do not have standards by which to judge whether or not a given level constitutes a health threat. We have not yet devised tests that can tell us if very small but frequent dosages of a pollutant taken over a period of 20 or 40 years can be harmful. Therefore, the detection of trace levels of toxics in the Missouri River now raises as many questions as it answers. Even without the guidance of good water quality standards for these pollutants, we should continue to monitor for them to develop a body of information upon which we can judge a future improvement or deterioration of water quality in the Missouri.

SUMMARY

As the only large river in a part of the country where annual rainfall is often inadequate to meet demand for water, and where most other streams carry only small volumes of water for most of the year, the Missouri has attracted many people and industries. Use of the river has led to water pollution. The pollution problems have changed as we have changed our use of the river. In 1910, the primary water quality concern in the Missouri was sewage contamination which could cause typhoid fever. That concern grew through the first half of the century to include other bacterial and viral water borne diseases. By the 1950's, the volumes of untreated organic wastes discharged from cities, meat packers and stockyards was so great that the physical appearance of the river and the reduced levels of dissolved oxygen became major concerns. This situation worsened into the sixties as wasteloads increased while waste treatment remained a rarity. By the mid 1960's, many major cities and industries began treating wastes, with dramatic improvements in the appearance of the river.

The main water quality concerns at present are the presence of toxic chemicals and the potential threat they pose to the use of the Missouri as a source of safe drinking water.

A chronology of events is presented below.

1910 —Increase in typhoid deaths in towns along the Missouri River.

1913 —The U.S. Public Health Service report identifies sewage pollution in the Missouri River as a major factor in the typhoid death rate.

circa 1920 - 1958 —Records kept by water suppliers and studies by the Public Health Service and state health agencies confirm rising levels of bacterial contamination. Treatment provided by most water suppliers does not meet USPHS standards.

1946 —The Public Health Service publishes a manual of recommended water treatment and disinfection practices.

1955-1958 —Low dissolved oxygen, grease, bacterial threat to river recreationists and general appearance of the river are identified problems in USPHS, state health department studies.

1956 —Passage of Public Law 84-660 strengthening federal clean water laws.

1957-1958 —Enforcement conferences among city, state and federal officials to develop a timetable for the construction of wastewater treatment works.

1960-1970 —Construction of primary wastewater treatment plants for major dischargers on the river.

1968-1970 —Extensive water quality studies document bacterial, viral and fecal contamination of the river and low dissolved oxygen levels. Problems are especially acute during rainy periods when much surface runoff enters the river. The states of Iowa, Nebraska, Kansas and Missouri set water quality standards for the Missouri to protect beneficial uses.

1970-1980 —Construction of secondary wastewater treatment plants for some major dischargers to the river.

CHAPTER 2
WATER QUALITY TRENDS AND EXISTING WATER QUALITY

BACTERIAL CONTAMINATION

Warnings that bacterial contamination was straining the ability of water treatment processes to provide safe drinking water came as early as 1913 from the U.S. Public Health Service. Since that time, however, bacterial contamination of the Missouri, as measured by total coliform bacteria, has continued to increase.

Figure 1
TOTAL COLIFORM TRENDS IN THE MISSOURI RIVER AT THE KANSAS CITIES AND ST. JOSEPH (from USPHS, 1952, Burkholder, 1981, and Hines, 1980)

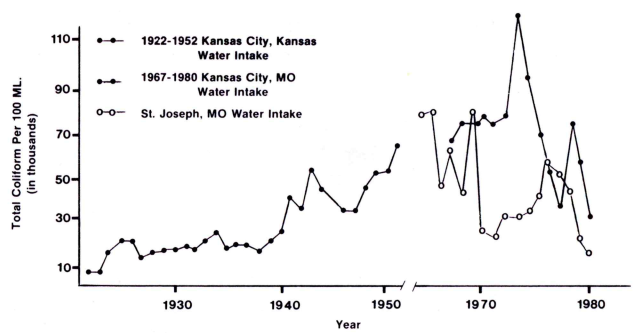
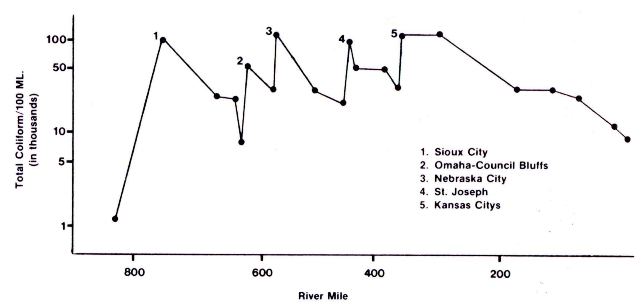


Figure 1 plots the increase in total coliform levels in the Missouri River at the Kansas City, Kansas, water intake from 1922-1951, and from the St. Joe water intake (1964-1980) and Kansas City, Missouri intake (1967-1980). The trend reflects the fact that population and wastewater volumes are continuing to increase in the St. Joseph, Leavenworth and Atchison area and the fact that disinfection of waste waters discharged to the Missouri is not practiced in Missouri or Kansas. There is some indication of lower levels during the past five years. Similar time trends could probably be seen for most sections of the river with the exception of areas near Sioux City or Council Bluffs, Iowa, where disinfection is now being practiced and localized large reductions in bacterial levels may have occurred.

Figure 2
ANNUAL MEDIAN COLIFORM BACTERIAL LEVELS IN THE LOWER MISSOURI RIVER, 1950



Coliform levels fluctuate greatly as water flows through the lower Missouri. Figure 2 shows that very high levels occur immediately below cities and/or large stockyards, followed by a general die-off then another peak at the next major source.

Fecal coliform concentration, an indication of fecal contamination of water, followed a similar spatial trend in the river. There is much less data on fecal coliform levels. The first extensive measurements of fecal coliform were made during surveys in 1968-1969. Regular monthly monitoring of fecal coliform levels did not begin until 1972. Figure 3 (on following page) summarizes much of the available fecal coliform data on the river.

The fecal coliform standard for whole body contact recreation (swimming and skiing) is 200 colonies/100 milliliters (ml), a value which is greatly exceeded at most places on the river below Sioux City. The standard for partial body contact recreation (fishing, boating) is 1000 colonies/100 ml for Nebraska and 2000 colonies/100 ml for Iowa and Kansas. Again, there are relatively few locations on the river where these standards are not violated.

Figure 3
FECAL COLIFORM BACTERIA CONCENTRATIONS IN THE MISSOURI RIVER

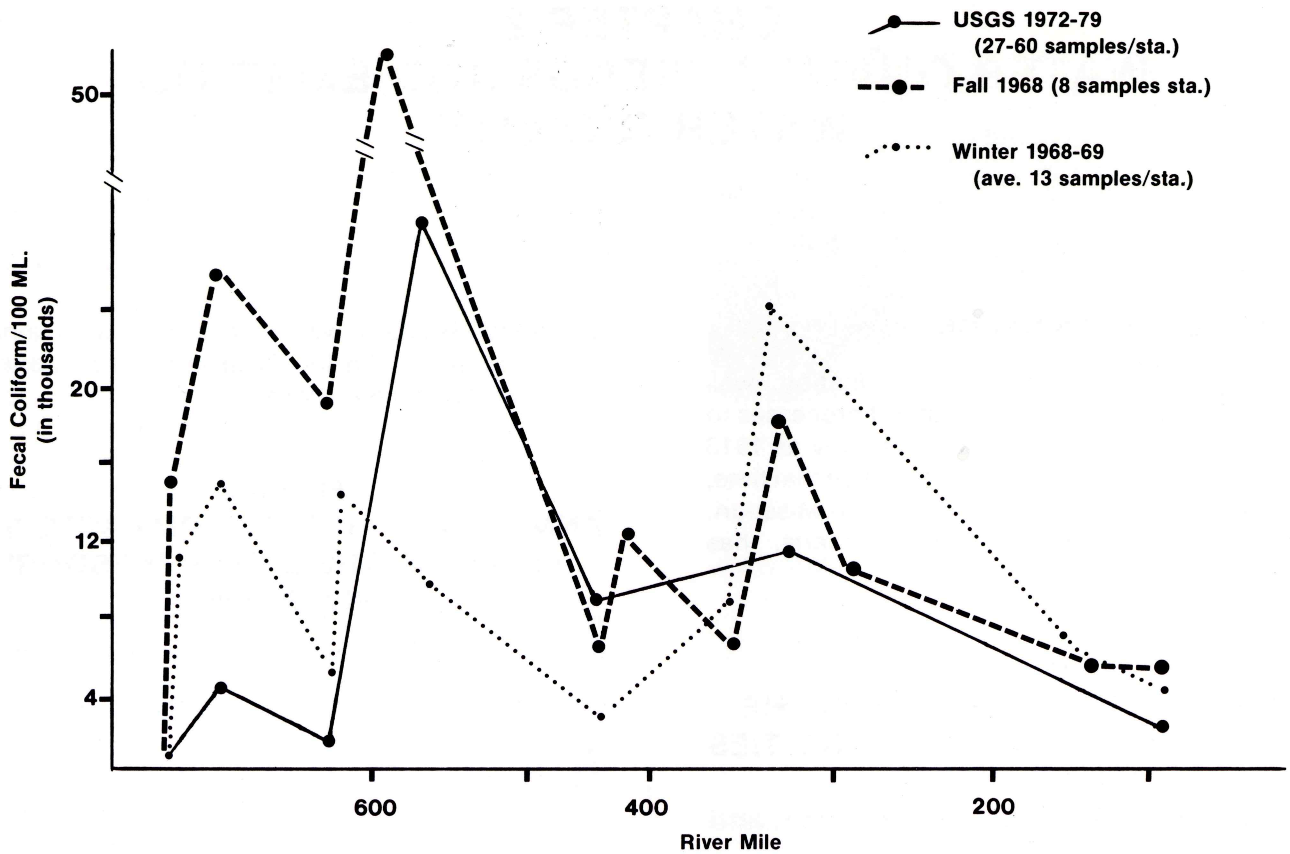
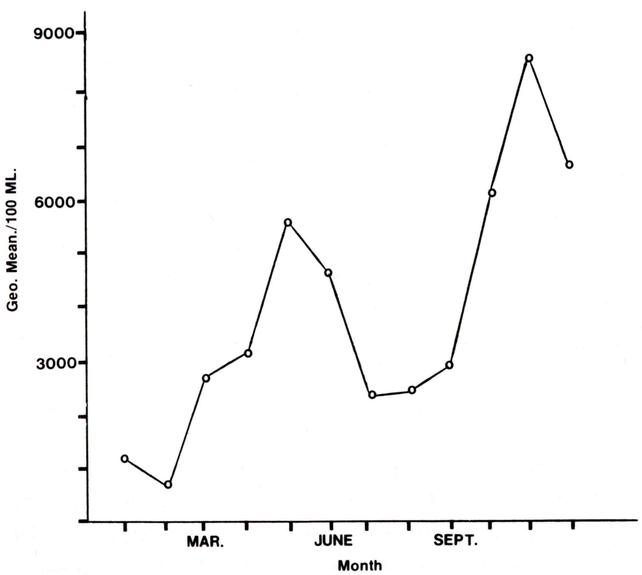


Figure 4
SEASONAL MEAN COLIFORM CONC. IN MO. R. AT ST. JOSEPH (1972-1979 USGS)



Seasonal trends in fecal coliform are not easy to interpret. Monthly geometric means at St. Joseph are shown in Figure 4. Late winter concentrations are low with sizable increases in spring and early summer corresponding to periods of maximum surface runoff and erosion. Elevated levels of fecal coliform in late fall and early winter do not correspond to periods of increased flow, high suspended solids, high nitrogen levels or low dissolved oxygen. This indicates that nonpoint runoff pollution is not reponsible for these high bacterial levels. Although Sioux City and Council Bluffs, Iowa, discontinue chlorination of wastewater effluents in October, these cities are believed to be too far upstream to affect bacterial densities at St. Joe. (Bellevue, Nebraska has practiced chlorination year-round since 1977). The increase may be due to increase coliform survival rates in the river.

It is difficult to discuss time trends for the fecal coliform data since there is so little of it. The only change that appears to be significant between the 1968-1969 data and the 1972-1979 data is the present lower levels of fecal coliform within the Sioux City to Omaha area which is probably due to chlorination at Sioux City and at Iowa Beef Packers in Dakota City, Nebraska.

Table 1
AVERAGE ANNUAL SUSPENDED SEDIMENT LOAD OF THE LOWER MISSOURI RIVER (in million tons)

Location	Approximate River Mile	Aver. Annual Prior to 1953	Sediment Load After 1955
YANKTON, SD	811	137.8	1.4
SIOUX CITY, IA	732		11.8
OMAHA, NE	626	163.8	28.6
NEBRASKA CITY, NE	562		47.1
ST. JOSEPH, MO	452	257.2	57.6
KANSAS CITY, MO	360	328.0	79.0
BOONVILLE, MO	180	350.0	
HERMANN, MO	100	326.2	100.8

SUSPENDED SOLIDS, TURBIDITY

Sizeable reductions in the amount of particulate matter (suspended solids) and in the murkiness of the water (turbidity) in the Lower Missouri resulted from impoundment of the main stem Middle Missouri (North and South Dakota). Impoundments on major tributaries such as the Kansas and Osage Rivers have also helped reduce solids and turbidity on the Missouri.

Table 1 compares annual suspended sediment load in the Lower Missouri before and after impoundment (Corps of Engineers, 1948, 1957, 1965, 1970, 1972, 1976). Prior to 1953, Fort Peck in Montana was the only main stem reservoir on the river, but by 1955, Fort Randall, Garrison and Gavins Point were all in operation.

Although reductions in suspended sediment are most spectatular immediately below the Gavins Point Dam, threefold reductions occur over 700 miles below Gavins Point showing the nature of the entire Lower Missouri has been changed. Not only has there been a long-term and rather abrupt trend of reduced suspended sediments, but more short-term influences can also significantly affect suspended sediment levels. Figure 5 shows how three variables (number of days since beginning of a significant increase in flow, discharge, and month of the year) affect suspended sediment levels. None of the variables significantly change suspended sediment concentrations at Sioux City, eighty miles below Gavins Point Dam. This is not surprising considering that the change and magnitude of discharge at Sioux City is almost entirely a function of releases of impounded water with consistently low concentrations of suspended sediment. It is interesting to note that none of the plotted values for these three variables falls outside one standard deviation of the mean.

The situation is quite different at Omaha, 185 miles below Gavins Point Dam. There is a strong relationship showing that the highest suspended sediment levels accompany the first few days of a significant rise in discharge and a somewhat weaker relationship suggesting that flows in the 40,000 to 50,000 cubic feet per second (cfs) range have higher levels of suspended sediment than at other levels of flow. The seasonal data shows highest levels occur in spring, but only the average for the month of May exceeds one standard deviation of the mean.

There are less available data for Hermann, Missouri, 700 miles below Gavins Point. It appears that discharge is the only one of the three variables plotted in Figure 5 (on following page) with a strong positive relationship to suspended sediment.

It is apparent, therefore, that the main stem impoundments have not only been instrumental in reducing suspended sediments throughout the Lower Missouri, but, in the first 100 miles below Gavins Point, have also eliminated most of the normal variability in suspended sediment concentration.

Turbidity of the river water was also reduced after impoundment. At the Kansas City, Kansas water intake, turbidities ranged from 1300-3200 ppm prior to impoundment and dropped to 470-800 ppm after impoundment, a decrease of 65%. At St. Louis, turbidities after impoundment decreased by more than 50% (Neel, 1963).

TOTAL DISSOLVED SOLIDS, SULFATES

Because of its large area, there are considerable climatic differences within the Missouri basin. Of particular importance are the lesser amounts of annual rainfall in the western part of the basin. This pattern of rainfall increases the relative importance of evaporation in the western and northern part of the basin and therefore the total dissolved solids (TDS) concentration. As the Missouri flows east and south, tributaries with lower TDS dilute the water of the Missouri. Thus, while the Missouri River in central Missouri has an average total dissolved solids (TDS) concentration of about 420 mg/l, the concentration in its major tributary in that location, the Grand River, is only 250 mg/l.

Figure 5
SUSPENDED SEDIMENT RELATIONSHIPS
MISSOURI RIVER
SIOUX CITY (DAILY W.Y. 74 & 75)
OMAHA (DAILY W.Y. 74 & 75)
HERMANN, MO. (MONTHLY W.Y. 1975-79)

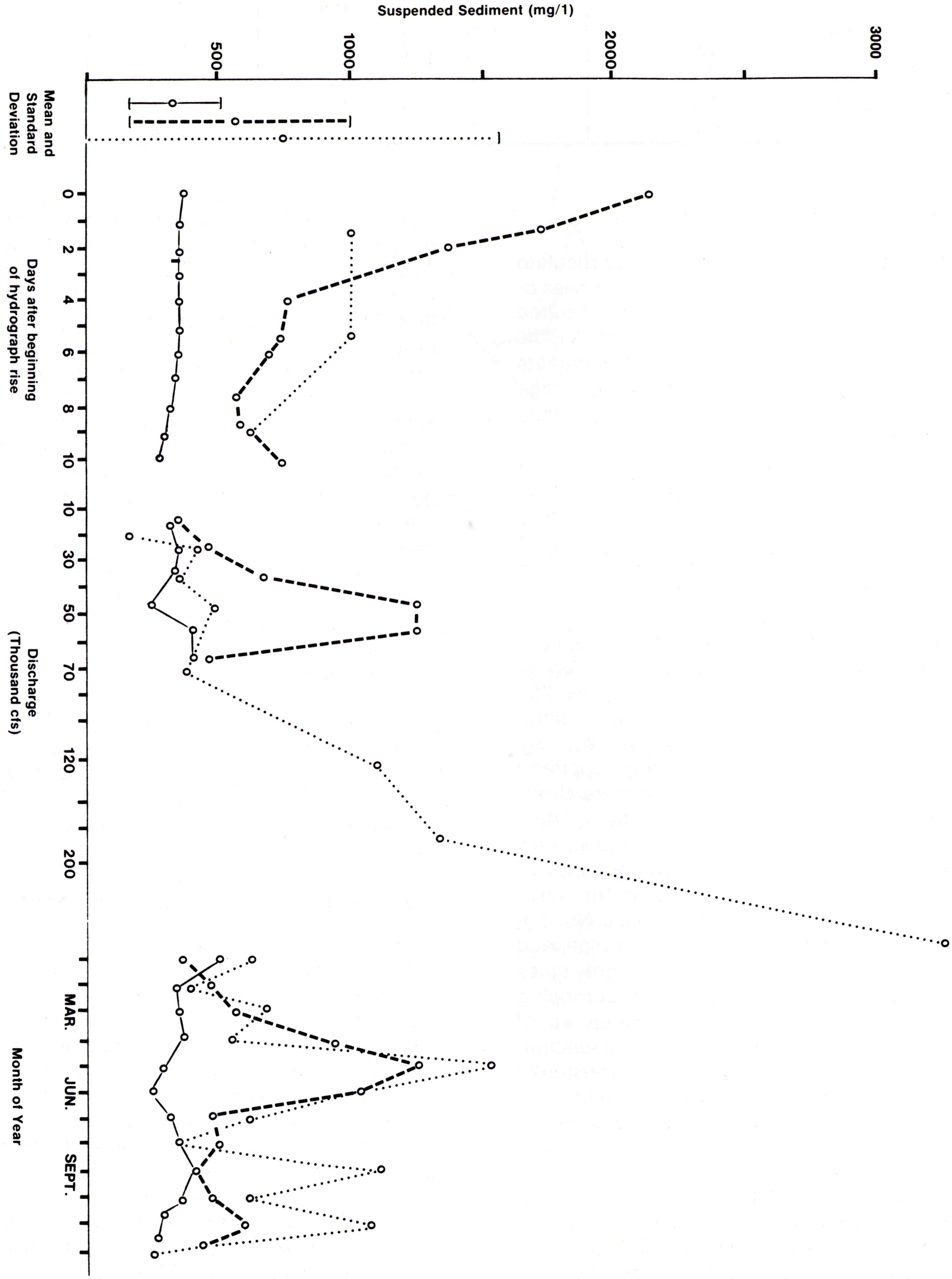
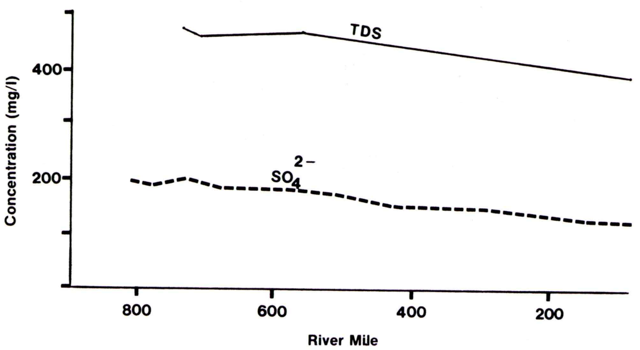


Figure 6
AVERAGE CONCENTRATIONS OF TDS AND SULFATE IN THE LOWER MISSOURI RIVER (USGS 1974-1979)



A similar situation exists for sulfate ion. Figure 6 shows the magnitude of downstream decreases in sulfates (approximately 25%) and total dissolved solids (approximately 15%).

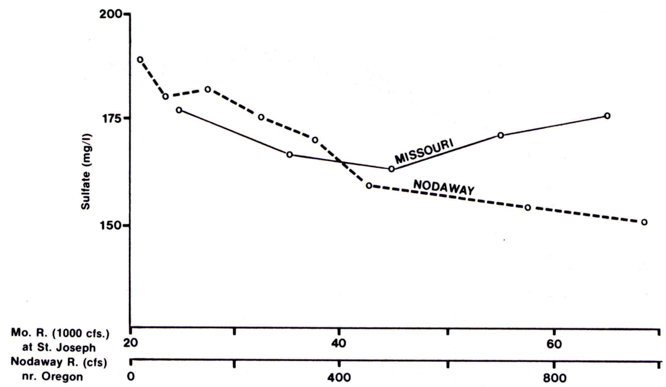
Trend analysis by linear regression and t-test for significance of slope was performed on all flows at St. Joseph. No significant trends over time were found. Similar analysis was made on monthly average TDS and sulfate levels from 1950 to 1979 on the Missouri near St. Louis. No significant time trend was detected for TDS on these data either. A slight but statistically significant trend of increasing sulfate concentrations with time was noted.

Shorter term trends are also apparent. The following discussion of short-term variability of sulfate should also apply for total dissolved solids.

Short-term variation in sulfate concentration in rivers typically has an inverse relationship with discharge, higher flows causing lower concentrations of sulfates and vice versa. The Lower Missouri, however presents a rather special case due to the main stem impoundments. The majority of the flow in the Lower Missouri comes from Gavins Point Dam, behind which is a large body of water with rather constant concentrations of sulfate. Therefore, increasing the released flow from Gavins Point Dam by several thousand cfs could make very significant changes int he flow in the Missouri without changing the sulfate concentration.

Actual observation of discharge - sulfate relationships bears out this point. At flows less than 70,000 cfs at St. Joe (which occur 90% of the time) there is no clear relationship between flow in the Lower Missouri and sulfate concentration. Since there is considerable variation in sulfate levels, however, their variablity must be due to tributary inflow. This assumption proves correct. Figure 7 shows sulfate in the Missouri has a much stronger relationship to flow on the Nodaway River, a tributary of the Missouri above St. Joe, than with flow in the Missouri itself.

Figure 7
THE RELATIONSHIP OF SULFATE IN THE MISSOURI RIVER AT ST. JOE TO FLOWS IN THE MISSOURI AND NODAWAY RIVERS

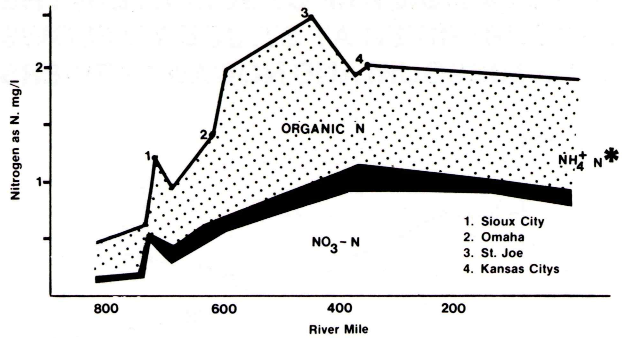


NITROGEN

While the major ions range in concentration from about 4 mg/l for potassium to 20 mg/l for magnesium and chloride to over 200 mg/l for sulfate, nitrogen (N) usually is found at concentrations of 1 to 2 mg/l. Although not a major constituent of Missouri River water, nitrogen is an important nutrient to both plants and animals in the river system. Eroding soils and discharges of organic wastes such as domestic sewage, stockyard and meat packing wastes are major contributors of nitrogen to the river. Therefore, even relatively small changes in nitrogen concentration can indicate the entry of nitrogen-rich pollutants into the river.

Nitrogen is most commonly found in one of three forms within the river: organic N, ammonia, or nitrate. Organic N is nitrogen contained in plant and animal material (living and dead) and animal and human wastes. Ammonia (NH_3) is produced by the bacterial decomposition of organic material. A conventional secondary wastewater treatment plant will contain almost the entire process of decomposition from organic N to ammonia with the plant. The third form of nitrogen commonly found in the river is nitrate N (NO_3). These oxidized forms are produced from ammonia by bacteria in the presence of oxygen. Unless a wastewater treatment plant has a special unit process for nitrification (the oxidizing of ammonia) the nitrogen discharge from the plant should be mostly ammonia and a small amount of nitrite plus nitrate N. The remaining nitrification takes place within the river and some of the dissolved oxygen in the river is used to form the nitrites and nitrates.

Figure 8
AVERAGE CONCENTRATION OF THE THREE MAJOR FORMS OF NITROGEN IN THE LOWER MISSOURI RIVER (USGS, 1974-1979)



*NOTE: **Ammonia in water found mostly as ammonium ion (NH_4^+) or ammonium hydroxide (NH_4OH). At the temperature and pH ranges encountered in the Missouri River, NH_4^+ accounts for 85 to 99.7% of all ammonia nitrogen.**

Figure 8 shows the distribution of nitrogen among the three major forms and how nitrogen concentrations change in various segments of the river. Due to settling of sediment-bound N and algal uptake, releases of impounded water from Gavins Point Dam are relatively low in nitrogen, but N increases dramatically between Sioux City and St. Joseph. At St. Joseph, average total N (organic plus ammonia plus nitrate) is five times higher than at Gavins Point. Such point source discharges as municipal sewage treatment plants, meat packing plants, and waste treatment facilities at stockyards are obvious contributors of nitrogen to the Missouri between Sioux City and St. Joseph.

Clearly point sources in the Sioux City and Omaha areas make a significant contribution. Figure 8 shows total N concentrations doubling from 0.6 to 1.2 mg/l within a short segment of the river in the Sioux City area. In the Omaha area the average concentration of total N increases from 1.35 to 2.0 mg/l. However, average increases in total N between Sioux City and Omaha (1.2 to 1.35 mg/l) and between Omaha and St. Joseph (from 2.0 to 2.4 mg/l) must be greatly influenced by nonpoint sources.

Nonpoint sources cannot be overlooked as major contributors of nitrogen to the lower Missouri. Tributaries drain some of the most erosive soils in the country and, undoubtedly, large amounts of nitrogen enter the Missouri through runoff. The influence of nonpoint sources becomes more apparent when nitrogen values are compared with increases in discharge. Figure 9 shows the relationship between total N and the number of days following a hydrographic event.* The data points appear to fit a linear or an exponential model equally well. Figure 10 shows the relationship between total N and discharge and suggests an exponential relationship. Both these trends indicate that nonpoint runoff does increase nitrogen concentrations in the Missouri and the slope of the regression lines suggest nonpoint sources are the major source of nitrogen during the times the river is receiving runoff.

Figure 9
THE RELATIONSHIP OF TOTAL N AND HYDROGRAPHIC RISES IN THE MISSOURI RIVER AT ST. JOSEPH, MO.

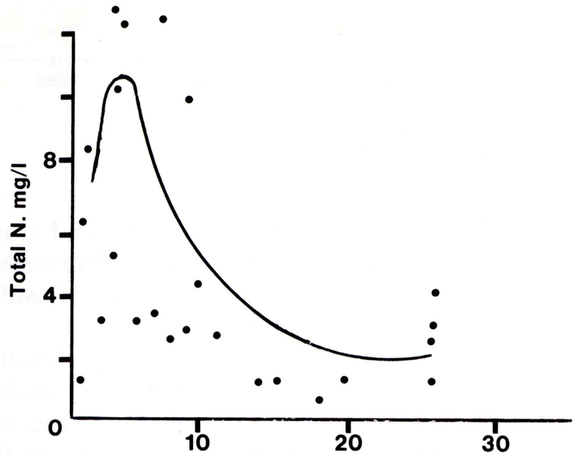
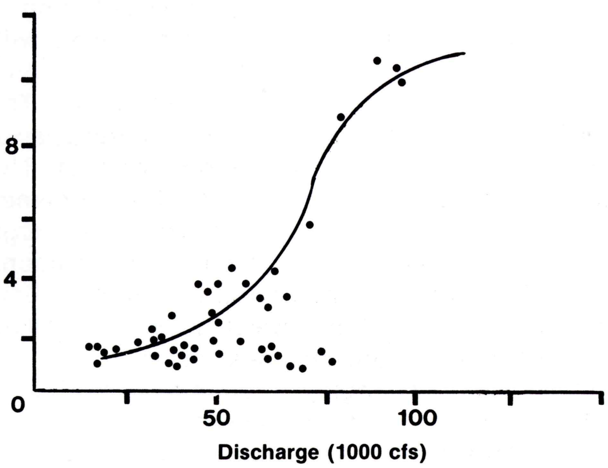
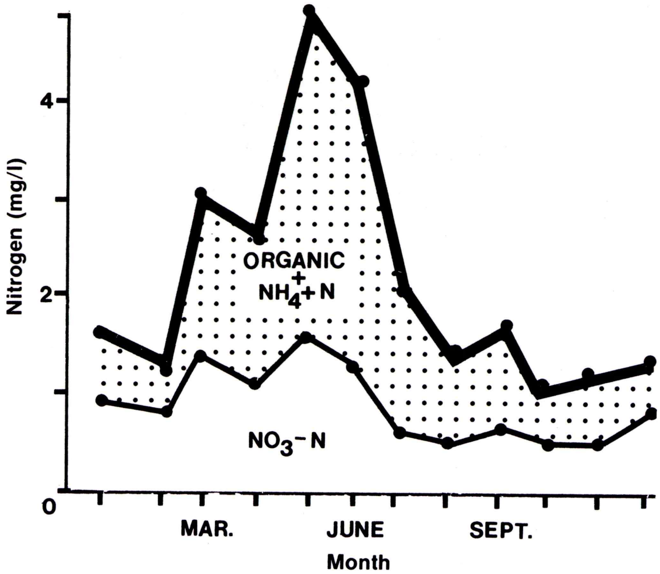


Figure 10
THE RELATIONSHIP OF TOTAL N AND DISCHARGE IN THE MISSOURI RIVER AT ST. JOSEPH, MO.



*** For the purposes of this report, a hydrographic rise was defined as an increase in discharge during a 48 hour period equal to or greater than 10% of the average discharge for the period of record.**

Figure 11
SEASONAL TRENDS IN NITROGEN IN THE MISSOURI RIVER AT ST. JOE. (USGS 1972-79)



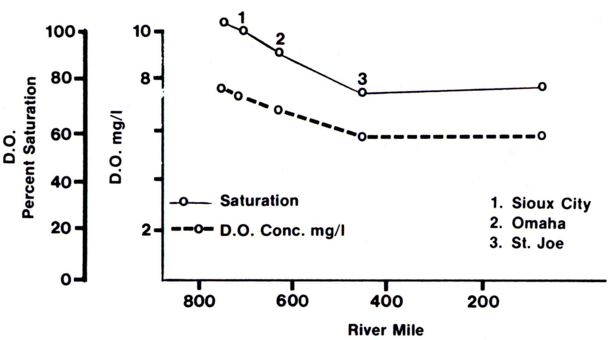
Seasonal trends in nitrogen concentrations are also evident. As shown in Figure 11, for the Missouri at St. Joe, the four months of highest nitrate nitrogen and organic nitrogen are the same: March, April, May and June. The same observations hold true over a 30 year period on the Missouri near St. Louis. This period corresponds to the interval between spring thaw and the development of good vegetative cover on tilled land, the period when the land is most susceptible to erosion.

Significant trends in nitrogen levels in the river over a period of years are much less discernable than trends over distance or season. Trend analysis by linear regression and t-test for significance of slope was performed on all flows for the period of record at St. Joseph (ten years). No significant trend with time was found for either nitrate or total N. Thirty years of nitrate and ammonia data on the Missouri near St. Louis was similarly analyzed. This analysis showed a significant trend of increases nitrate and ammonia levels over the last 30 years.

DISSOLVED OXYGEN

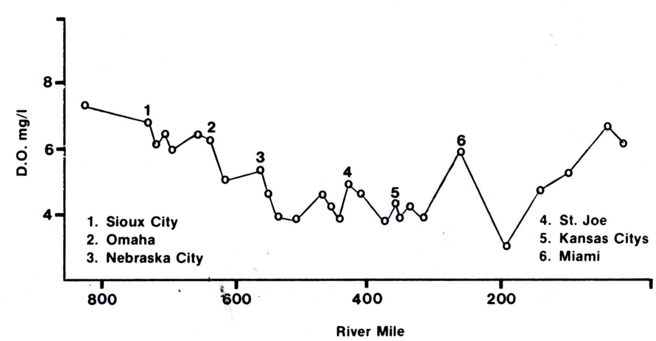
All four states bordering the Lower Missouri set a minimum DO standard of 5 mg/l for the protection of fish and other aquatic life requiring oxygen in the water. There is abundant dissolved oxygen in the upper part of the Lower Missouri throughout the year, and for the entire lower river from late autumn to early spring. During the warm weather months, increasing oxygen demand of waste discharges lowers the DO in the river as the water flows downstream. Figure 12 plots average saturation values for oxygen for various sections of the river and also shows the corresponding DO concentration at a warm water temperature of 28° C.

Figure 12
MEAN D.O. SATURATION VALUES AND CORRESPONDING D.O. CONCENTRATIONS AT 28° C., MISSOURI RIVER (USGS 1974-79)



No segment of the river violates the DO standards under "average" river conditions, but the occasions of D.O. minima are much more important since they represent the critical period for fish and other aquatic animals.

Figure 13
MINIMUM DISSOLVED OXYGEN LEVELS MISSOURI RIVER, JUNE—SEPT. 1950

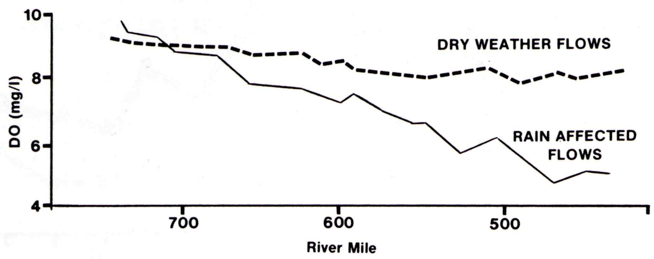


Periods of low dissolved oxygen concentration were noted as early as 1913 when values as low as 4.3 and 3.1 mg/l were recorded at Atchison and Leavenworth, Kansas, respectively. In 1945, Berner (1951) noted that saturation values as high as 95 percent occurred on the river near St. Joseph during periods of clear water, but when flows were high and muddy the DO could drop to only 50 percent of saturation. He measured a DO minimum of 3.5 mg/l near St. Joseph. A 1950 study (USPHS, 1952) found DO minima became lower as the river moved downstream. This information, presented in Figure 13, shows violations of the 5 mg/l standard began to occur below Nebraska City, Nebraska (approximately at river mile 550) and persisted

throughout the river to Hermann just 100 miles above the mouth. DO minima at most stations were recorded during one of two high flow periods that occurred during that four month period, lending support to Berner's earlier observations that lowest DO's were during high flows. (The apparent recovery of DO near Miami, Missouri, below Kansas City is probably not accurate since DO's at the 10 stations immediately above Miami were sampled during high flows on August 15-16 while Miami was sampled at a lower flow on August 14.)

The most dramatic and damaging recorded incident involving low DO's at high flows occurred in 1964. Heavy rains along the Missouri Valley during May 23-26 swelled the river, flushing in organic materials from urban and rural areas and resuspending pollutants previously deposited on the riverbed. The appearance of dead fish in a 120 mile segment of the river from Leavenworth, Kansas to Waverly, Missouri, 80 miles below Kansas City, was noted on May 26-27. This fish kill prompted sampling of the river on May 29 by the Public Health Service. The DO profile of the river based on that sampling (Figure 14) left little doubt that a pulse of water of very low DO (possibly completely deoxygenated water a day or two prior to the May 29 sampling) was responsible for the fish kill.

Figure 15
DISSOLVED OXYGEN CONCENTRATIONS IN THE MISSOURI RIVER OCT.-NOV. 1968 (Ballentine, 1970)



Extensive sampling of the river in the fall of 1968 graphically portrayed the effect of runoff on dissolved oxygen. Shown in Figure 15, the effects are unnoticed near Gavin's Point as expected, but as DO concentrations begin to decrease downstream, the rate of decrease is accelerated during runoff conditions.

Although not ideally located for addressing localized point source impacts, sampling by the USGS throughout the 1970's has generally affirmed that the 5 mg/l standard which the FWPCA sought to protect (Table 2) is not being violated during stable flows. Table 3 summarizes the USGS data. Only at Sibley, Missouri, 30 miles below Kansas City, is there an indication of DO violations caused primarily by point source discharges.

Figure 14
DISSOLVED OXYGEN PROFILE OF THE MISSOURI RIVER FROM ST. JOSEPH TO ROCHEPORT
May 29, 1964

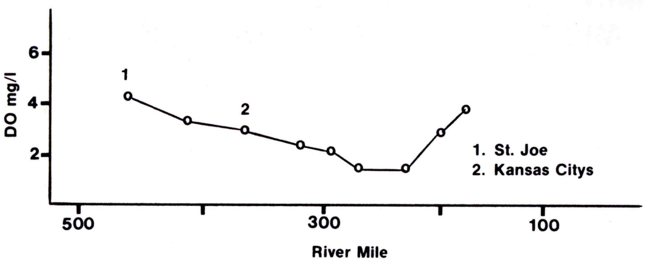


Table 2
FLOW REQUIREMENTS, LOWER MISSOURI RIVER (CFS)

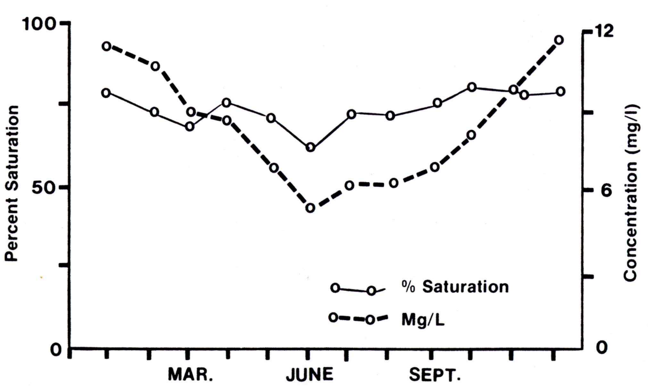
Location	Minimum Flow To Protect Dissolved Oxygen Standard June-Sept.	Minimum Flow For Navigation Apr.-Nov.
SIOUX CITY	3,000	30,000
OMAHA	7,500	≅ 31,000
KANSAS CITY	9,000	32,500

Table 3
SUMMARY OF DISSOLVED OXYGEN DATA FOR THE LOWER MISSOURI RIVER (USGS, 1970-1979)

Location	Approx. Mile	Period of Record	No. of Analyses	Total No. of Violations	Violations During Rain Affected Flows	Violations During Stable Flows
SIOUX CITY	732	1974-75 1977-79	69	0	0	0
DECATUR, NE	691	1974-75 1977-79	69	0	0	0
OMAHA	626	1979	11	0	0	0
ST. JOSEPH	448	1971-79	108	5	5	0
SIBLEY, MO	340	1972-75	49	7	4	3
HERMANN, MO	98	1971-79	108	6	5	1
TOTAL			414	18(4%)	14(3%)	4(1%)

Seasonal trends are also evident for dissolved oxygen. Figure 16 shows the seasonal effect in DO concentration due to gas solubility changes with water temperature. As temperatures increase, the amount of gas which can dissolve in water decreases. Of more interest in explaining water quality changes in the river is the seasonal plot of percent saturation which shows DO changes independent of temperature. Lowest monthly average saturations are in March, May and June, which correspond with highest levels of nitrogen in the river, suggesting the importance of non-point sources of organic, oxygen demanding waste inputs during this time of the year.

Figure 16
SEASONAL DISSOLVED OXYGEN TRENDS IN THE MISSOURI RIVER AT ST. JOE (USGS 1972-1979)



Time trend analysis by linear regression and t-test for significance of slope was performed for all data at St. Joseph. This procedure showed no significant trend over time.

Since the mid 1960's, primary or better treatment of all major discharges has reduced the amount of organic solids in the river. This has reduced the problem of resuspending oxygen demanding solids from the river bed during high flows which should have the effect of reducing the severity of these low DO events. The small amount of DO data prior to 1970 prevents characterizing this trend quantitatively.

METALS

The constituents of water discussed so far (DO, suspended sediments, TDS, sulfate and nitrogen) are found in the river in concentrations greater than 1 mg/liter (1 part per million). Metals in the Missouri are found in much smaller quantities and the amounts are measured in micrograms per liter (ug/l) or parts per billion. Although the concentrations of metals may be less than one one-hundredth or one one-thousandth of that of the major ions, certain metals can be toxic to fish and other aquatic life at these very low levels. Other metals such as iron and manganese exhibit very little toxicity but can cause such water supply problems as staining of laundry, taste and odor in drinking water and scale build-up in pipes.

Table 4 lists those metals routinely monitored on the Missouri by the USGS and the frequency with which violations occur. Highest frequency of violations is by mercury. As mentioned earlier, the allowable amount of mercury is extremely small, reflecting our concern over mercury poisoning of fish, ducks, shore and wading birds, predatory birds and people who eat fish. Research has shown that any form of mercury can be converted to methyl-mercury which is easily assimilated by animals. Although the standard rightly reflects the dangers of even small amounts of mercury, such natural processes as rock weathering and soil erosion alone can cause violations of the standard. Mercury is used as a fungicide-germicide and has industrial applications as a catalyst in certain chemical

reactions. Runoff from golf courses, discharges from chlorine plants and discharges from large urban wastewater treatment plants can all be important sources of mercury.

Table 4
FREQUENCY OF VIOLATION OF WATER QUALITY STANDARDS FOR SELECTED METALS

Metal	Per Cent in Time in Violation of Standards	Standard Violated
MERCURY	33	AL*
MANGANESE	8	DW(S)**
IRON	3	DW(S)
COPPER	3	AL
SELENIUM	3	DW***
ZINC	3	AL
CADMIUM	2	AL, DW
LEAD	2	AL, DW
ARSENIC	0	———
CHROMIUM	0	———
SILVER	0	———

*** protection of aquatic life; ** protection of aesthetic qualities of drinking water supply; *** protection of health, drinking water supply**

(S) denotes secondary or aesthetic standard

The Food and Drug Administration (FDA) has set a limit of 0.5 mg/kg (one-half part per million) for mercury in food shipped to interstate markets, but there are few mercury analyses of Missouri River fish to compare to the standard. In 1977, the U.S. Fish Pesticide Lab in Columbia, Missouri (1980) found the average mercury content of fish sampled at Nebraska City, Nebraska, was 0.06 mg/kg and at Hermann, Missouri, 0.24 mg/kg. Background levels ranging from 0.04 to 0.76 mg/kg and 0.03 to 0.18 mg/kg have been reported from Canada and Sweden, respectively (Wisc. DNR, 1972). Therefore, despite frequent violation of the mercury standard in the water, there is no evidence of significant mercury accumulation in fish.

The second most frequent metals standard violation is for manganese. Much manganese and iron enter the river via water movement through or erosion of soils, and some is added from municipal and industrial discharges. Neither manganese nor iron presents a frequent problem.

The two selenium violations were both recorded at Hermann, Missouri, in 1970-71. No values since then have approached these levels and they are believed to have been inaccurate measurements.

As Table 5 shows, the standard for protection of aquatic life was violated three times for copper and zinc and twice for lead and cadmium. The causes are unknown. The United States does not have standards for fish flesh contamination by these metals, but Canada does have standards for lead, zinc, copper and for arsenic. Sampling by the U.S. Fish Pesticide Lab in 1977 showed that levels of arsenic and lead in Missouri River fish was well

Table 5
SUMMARY OF METALS MONITORING ON THE LOWER MISSOURI RIVER (USGS 1970-79)

	Sioux City		Neb. City		St. Joe		Hermann			
Metal	N*	V**	N	V	N	V	N	V	Freq.	Std. Viol.
IRON	17	0	12	0	75	3	39	2	.03	DW(S)***
MANGANESE	35	2	12	0	75	9	40	2	.08	DW(S)
ARSENIC	47	0	9	0	16	0	24	0	.00	
CADMIUM	46	1	9	0	20	1	35	0	.02	DW, AL
CHROMIUM	46	0	9	0	20	0	35	0	.00	
COPPER	46	0	9	0	20	0	35	3	.03	AL
LEAD	46	1	9	0	20	0	35	1	.02	DW, AL
MERCURY	12	4	9	3	20	6	34	12	.33	AL
SELENIUM	14	0	9	0	20	0	33	2	.03	DW
SILVER	25	0	NA		4	0	12	0	.00	
ZINC	47	0	9	0	20	0	35	3	.03	AL
FREQ.		.02		.03		.06		.07		

*** N = No. of analyses** **** V = No. of violations**
***** (S) = Secondary (Aesthetic) Standard**

below the Canadian standard (Table 6). No analyses were made for copper and zinc.

The data on metals violations in water are shown in Table 5. Metals violations of water quality standards are infrequent on the Missouri, particularly on that segment of the river bordering Nebraska and Iowa, and to date there is no evidence that fish contamination by metals is occurring.

Table 6
LEVELS OF SELECTED METALS IN MISSOURI RIVER FISH AND RELATIONSHIP TO ESTABLISHED STANDARDS (mg/kg)

Metal	Missouri R. Fish	Canadian Standard
ARSENIC	0.08	5.00
LEAD	1.02	10.00
CADMIUM	0.04	no standard
ZINC	?	100.00
COPPER	?	100.00

PESTICIDES AND PCB's

Pesticides and PCB's, like metals, are found in very small quantities in most waters and can be toxic to aquatic life even in small quantities.

Pesticides have been monitored by the USGS on the Missouri at Sioux City since 1977 and at St. Joseph and Hermann since 1972. Findings and comparisons to standards are shown in Table 7.

The USGS data shows only dieldrin and DDT occasionally violating water quality standards. Sampling done by the State of Iowa between 1968-1976 at Council Bluffs indicates higher frequencies of violations. DDE, a metabolite of DDT, was in violation of standards 33 percent of the time, while dieldrin was in violation 13 percent and DDT, 9 percent of the time. The difference between these frequencies and those of the USGS may be due to the sensitivity of the laboratory equipment and possibly to the decline in the use of dieldrin and DDT. Most uses of dieldrin and DDT were forbidden by the USEPA in the mid 1970's and there has been little use of these insecticides in agriculture since that time. The continued occurrence of DDT and dieldrin is expected to become less important problems in the future as they are gradually flushed out of the river system and their use continues to decline.

There has been very limited water sampling of polychlorinated biphenyls (PCB's) by the USGS at St. Joseph and Hermann, and in both locations, none were detected.

PCB's and many pesticides, however, can accumulate in fish and other animals many thousand times their concentration in water. The FDA has set limits on the maximum allowable concentration of dieldrin (0.3 mg/kg) and PCB's (2.0 mg/kg) in fish flesh. Table 8 shows maximum levels and frequency of violations of the dieldrin and PCB standards for fish based on work done by the U.S. Fish Pesticide Lab (1980), Lorenz (1976) and the Missouri Department of Conservation (1976).

Table 7
MAXIMUM PESTICIDE CONCENTRATIONS AND FREQUENCY OF VIOLATIONS IN THE MISSOURI RIVER in ug/1 (USGS 1972-79)

	Maximum Concentration			Aquatic Life	Frequency of
Pesticide	Sioux City	St. Joe	Hermann	Standard	Violation
DIELDRIN	ND*	.01	.02	.003	.12
DDT	ND	.02	.01	.001	.04
2, 4-D	ND	.97	.44	100.00	.00
2, 4, 5-T	ND	.01	.10	10.00	.00
SILVEX	ND	ND	.37	10.00	.00
DIAZINON	ND	ND	.04	no standard	——
MALATHION	ND	ND	.03	.10	.00
ATRAZINE	ND	1.8	4.7	no standard	——

NOTE: an additional 18 pesticides were monitored for at all three locations but were never detected in any samples.

*** Not detected**

Table 8
MAXIMUM CONCENTRATIONS OF DIELDRIN AND PCB's IN FISH (mg/kg) AND FREQUENCY OF VIOLATION OF F.D.A. STANDARDS

Location	Constituent	Maximum Concentration	Frequency of Violation
YANKTON, SD	PCB	0.39	.00
SIOUX CITY, IA	PCB	0.85	.00
OMAHA, NE	PCB	0.20	.00
NEBRASKA CITY, NE	DIELDRIN	0.17	.00
	PCB	3.12	.13
ST. JOSEPH, MO	PCB	0.25	.00
KANSAS CITY, MO	PCB	0.08	.00
BOONVILLE, MO	DIELDRIN	0.29	.00
	PCB	0.81	.00
JEFFERSON CITY, MO	PCB	0.50	.00
HERMANN, MO	DIELDRIN	1.10	.52
	PCB	9.50	.36

Table 8 shows that dieldrin violations of the FDA standard are frequent in the Hermann area but not in the more upstream sections of the Lower Missouri. The PCB violations are at Nebraska City and at Hermann, the two stations which have been sampled most frequently. Some fish at Hermann have exceeded the PCB standard by nearly a factor of 5. During the past few years the PCB level in fish at Hermann has declined sharply, but the number of samples have been too small to produce a statistically significant trend.

Levels of pesticides and PCB's need to be monitored more frequently, particularly in the lower section of the river. The frequency of violations to date indicates that the restrictions placed on dieldrin were well-founded and we should carefully monitor PCB's in fish to see if more control of PCB disposal is needed.

SUMMARY

This chapter has presented information on several constituents in Missouri River water. It is summarized in three ways: one, by listing where and when those constituents violate water quality or fish flesh standards; two, by noting how the constituent changes as the water flows from Gavin's Point Dam over 800 miles to its mouth and how it is affected by rain; and three, whether or not there has been a long-term trend in the amounts of that constituent. This information is presented in Tables 9-10 and Figures 17-18.

Table 9
SUMMARY OF WATER QUALITY AND FISH FLESH STANDARD VIOLATIONS ON THE LOWER MISSOURI RIVER

Constituent	Standard Violated	Location and Frequency of Violation
Fecal Coliform Bacteria	Whole Body Contact Recreation & Partial Body Contact Recreation	All the river bordering Nebraska and Iowa (and Kansas for Partial Body Contact) below Sioux City, Iowa. High frequency of violation.
Dissolved Oxygen	Protection of Aquatic Life	During stable flows, (in slackwater areas) below major discharges (Omaha, St. Joseph). Low frequency and then only during summer and early fall. During rain-effected flows, entire river below Omaha; high frequency of violation during summer and fall.

Mercury, Copper, Cadmium, Lead	Protection of Aquatic Life	Throughout entire river (except copper which may be a problem only in the lower end). Mercury high frequency of violation, others low.
Iron, Manganese	Secondary Drinking Water	Entire River, low frequency of violation.
Cadmium, Lead	Primary Drinking Water (Health)	Entire river, low frequency of violation.
Dieldrin, DDT	Protection of Aquatic Life	Entire river below Omaha, Dieldrin moderate frequency, DDT low frequency of violation.
PCB's, Dieldrin	Contamination of Fish Flesh	Entire river below Omaha, low to moderate frequency (there are very few samples from which to judge quency of violation.

Table 10
SUMMARY OF DOWNSTREAM AND RAIN-AFFECTED WATER QUALITY TRENDS

Constituent	Downstream Trend	Rain Affected Trend
Fecal Coliform Bacteria	Lower amounts at extreme upstream and downstream ends, higher amounts from Sioux City, IA, to Jefferson City, MO. Within the area of high concentration levels are highest immediately below large cities and gradually decline until the discharge from the next large city.	Runoff greatly increases fecal coliform concentration throughout the river.
Total Nitrogen	Low at extreme upsteam end. Increases from Sioux City to St. Joseph then declines slightly in the lower river.	Runoff greatly increases concentration throughtout the river.
Dissolved Oxygen	The inverse of total N. High at extreme upstream and decreasing from Sioux City through the Kansas City area with a slight rise in the lower river.	Runoff greatly decreases concentration throughout the river.
Suspended Solids	Continual increase in concentration.	Runoff greatly increases concentration except at upstream end which is little affected
Total Dissolved Solids, Sulfates	Continual decrease in concentration.	Runoff causes a decrease in concentration throughout the river.
Heavy Metals, Pesticides, PCBs	Insufficient data to evaluate quantitatively.	Insufficient data to evaluate quantitatively.

Figure 17
SPATIAL TRENDS FOR SELECTED CONSTITUENTS OF MISSOURI RIVER WATER

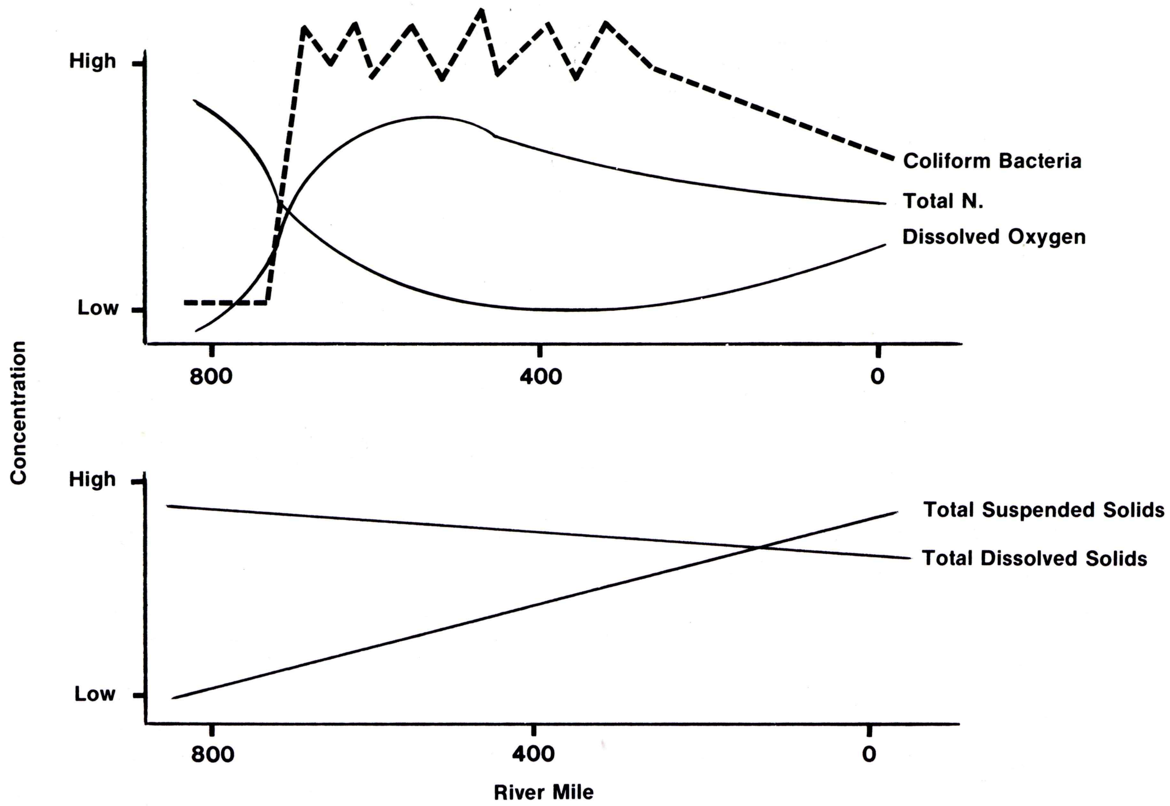
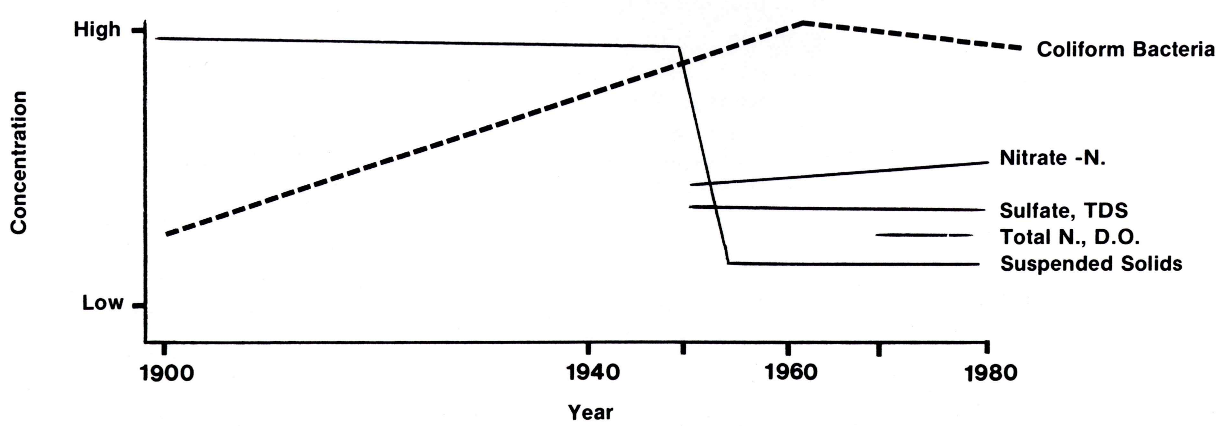
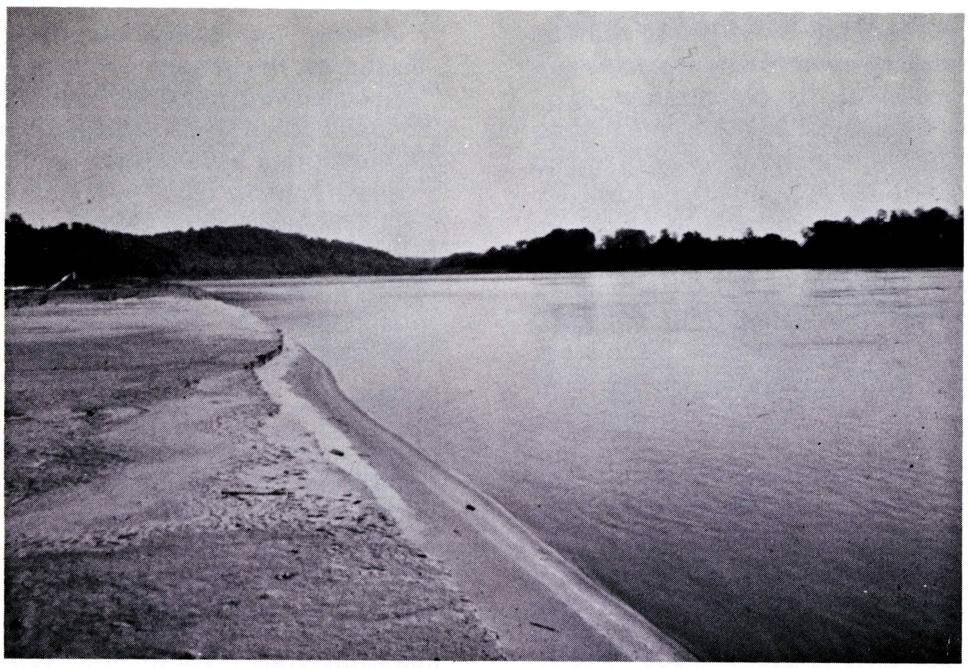


Figure 18
SUMMARY OF TIME TRENDS FOR SELECTED CONSTITUENTS OF MISSOURI RIVER WATER



CHAPTER 3
WATER QUALITY EFFECTS ON THE AQUATIC BIOTA



ALGAE

Ellis (1937) expressed the opinion that turbidity was perhaps the most important single factor limiting aquatic life in the Missouri River. Berner (1951) measured algal densities in the Lower Missouri in 1945 and found them much lower than those of other large rivers. He attributed the lower density to high current velocity, lack of adjoining lentic areas, and to turbidity of the water. The results of several later algal surveys of the Missouri and its tributaries found greater diversity of the algal flora in the tributaries. Regardless of the more important species in the tributary, the same few species always predominated in the Missouri, indicating only certain species originating in the tributaries were surviving in the Missouri (Neel, 1963). Turbidity seemed the most likely cause.

Impoundment in the main stem reservoirs, as mentioned in the preceding chapter, caused substantial decreases in turbidity and suspended sediments. A study of algal populations of the main stem reservoirs (Neel, 1963) provided evidence that water clarity did increase algal populations in the river. Comparison of Berner's 1945 data on algal densities in the Missouri near St. Joe with more recent data at that location is difficult since Berner made counts in terms of "individuals," the most dominant of which were the colonial forms *Pediastrum* and *Fragilaria.* Even assuming an average of 50 cells per "individual" gives 2,200 cells per liter in 1945 compared to almost 11 million cells per liter average for April-October, 1977-1979 (USGS 1977 - 1979). A very exaggerated estimate of 1,000 cells per "individual" for Berner's data leaves the 1945 algal densities very low compared to more recent levels. The smaller amount of data collected by Berner probably does not justify using the above figures to estimate the amount of increase in algal density caused by impoundment, but it does indicate the increase has been substantial.

Impoundment may also have been instrumental in changing the relative importance of the major taxa. Table 11 compares information from Berner (1951) and the USGS (1977-1979).

BENTHOS

As with the algae, Berner and many succeeding

Table 11
COMPARISON OF MAJOR ALGAL TAXA, LOWER MISSOURI RIVER BEFORE AND AFTER IMPOUNDMENT

Family	1945 (Berner)	1977-79 (USGS)
Green Algae	*Pediastrum*	*Scenedesmus*
Diatoms	*Fragilaria*	*Asterionella* *Cyclotella*

workers have found very low denisities of benthos (bottom dwelling organisms) in the Lower Missouri. The physical constraints to colonization (e.g., shifting, unstable substrates, siltation, fluctuating water level, swift current and the absence of rooted aquatic plants) keep benthic populations low.

In areas where he did quantitative sampling, Berner considered areas of the channel near steep banks to be most productive. He did not attempt to quantitatively sample the debris that collected upstream of the pile dikes, but implied these areas were probably the most productive on the river because of the reduced current and the presence of a stable substrate.

Several studies have attempted to measure the effects on benthos of waste heat discharged to the river by power plants. These studies typically note the highest densities of benthos occur on wing dikes and revetments made of rock and on pile dikes. These areas represent the most stable substrates in the river system. Other areas, particularly the bottom in the main channel, have low densities of benthos. Significant water quality effects on benthos in the river have not been documented by these power plant thermal studies (Neb. Public Power District, 1975, 1978; Union Electric Company, 1974). Table 12 summarizes the major components of the benthos and the most productive habitats.

Table 12
IMPORTANT HABITAT TYPES OF THE LOWER MISSOURI RIVER AND ASSOCIATED BENTHOS

Habitat	Benthos
Rip-rapped Dikes and Revetments	Trichoptera (Caddisflies) Ephemeroptera (Mayflies) Diptera (True Flies)
Silt-mud Bottom Below Dikes and Revetments	Oligochaeta (Segmented Worms) Chironomidae (Midges: A Subfamily of the Diptera)

Among the various water quality problems discussed, the periodic low dissolved oxygen levels associated with runoff is the only one of importance to the benthos. The caddisflies, mayflies, and many of the diptera have oxygen requirements similar to those of fish and could be affected if DO values drop much below 3 mg/1. However, the overall water quality constraints to the development of a large and diverse benthic fauna are relatively unimportant in comparison to the constraints imposed by the physical nature of the river.

FISH

Fish are the most obvious and commercially important members of the aquatic biota of the Missouri River. Consequently, more is known about them and their relationship to water quality than is known about the various species of algae and benthic invertebrates.

Turbidity Effects

The Missouri was certainly a muddy river long before man came along to till the soil. In his study of fish distribution in Missouri, Pflieger (1975) notes that differences in turbidity between the Missouri and the Mississippi above the Missouri were great enough for that confluence to act as a boundary for the distribution of at least 12 species of fish.* Since the major trend in turbidity has been a decrease due to impoundment of the Middle Missouri, no turbidity related problems have developed. In fact, Pflieger (1975) considers the reduced turbidity the reason for the recent appearance of the White Bass, *Morone chrysops,* in the Lower Missouri.

Dissolved Oxygen

As previously noted, the dissolved oxygen standard is often violated for the entire river below Omaha during rain-affected flows in the summer and autumn. The 5 mg/l standard was established to maintain a diverse fish fauna. Considerable

*** The Pallid Sturgeon, Sicklefin Chub, Sturgeon Chub, Flathead Chub, Plains Minnow and Western Silvery Minnow are found in the Missouri and the Mississippi below the Missouri, but not in the Mississippi above the Missouri. The Logperch, Slenderhead, River and Western Sand Darters, the Stonecat and the Freckled Madtom have the opposite distribution.**

research on DO levels and fish mortality has been done, but the number of other variables involved in a natural river system makes it impossible to state definitively the level of DO that will cause mortality to a particular species of fish. In general, it would appear that summer DO concentrations of 2-3 mg/l could cause some selective mortality by species, age or physiological condition. DO levels below 2 mg/1 for a sustained period of time (2 to 3 days) would undoubtedly cause extensive fish mortality. One documented fish kill due to low DO has been recorded over a 120 mile segment of the river in the Kansas City area in 1964.

Toxic Substances

Regular monitoring programs documented seven substances in water which violated standards for protection of aquatic life (Tables 5, 7). These 7 were mercury, lead, cadmium, copper, zinc, DDT and dieldrin. At present, the only substances exceeding acceptable levels in fish flesh are dieldrin, mentioned above, and PCBs, which have not been detected in the water. However, the present frequency of monitoring is very low and significant events such as spills can be easily missed.

One such spill occurred when a pesticide warehouse burned in Omaha in 1965. A report (Clare, 1965) of the incident considered levels of parathion dangerous in a 50 mile stretch of the river below Omaha. Maximum recorded concentrations of parathion ranged from 6.57 ug/1 at the Council Bluffs water intake to 0.044 ug/1.

Other potentially toxic substances may present a threat to fish in the Missouri but have not been sampled for. For example, the introduction of free chlorine from the disinfection of wastewaters into the Missouri causes the formation of toxic substances called chloramines. Total residual chlorine (TRC), free chlorine plus chloramines, is toxic to warm water fishes in concentrations ranging from 0.09 to 0.30 mg/l. Research on the environmental fate of chloramines in water is not conclusive. Some work suggests they are very short-lived and are potential problems only in the immediate area downstream of chlorinated discharges. Other research suggest they are longer lived. Bender (1975) found that monochloramine, the most stable fraction of TRC, had a half life of about one day.

No monitoring of chloramines is known from the Missouri River. The major chlorinated wastewaters discharges are at Sioux City and Council Bluffs, Iowa. Assuming a total residual chlorine in wastewater effluent of 1.5 mg/1 (Bender, 1975) at Sioux City and a flow of 30,000 cfs, complete mixing would yield a TRC of somewhat less than 1 ug/1. The standard for protection of aquatic life is 10 ug/1. Since complete mixing does not occur quickly in large rivers, chloramines may be a problem within mixing zones below chlorinated wastewater discharges.

Toxicity of unknown origin was demonostated on caged fish in 1969 during a fish tainting study. Channel catfish caged in the Missouri just below the Big Blue River in Kansas City, Missouri, died within 24 hours. Those fish caged in the Big Blue died in four hours, while those caged in Sugar Creek, another tributary in the Kansas City area, were dissolved except for skin and bones in 96 hours, according to the report.

To summarize, industrial and municipal toxicants may be significant within mixing zones in the Missouri and persistent compounds such as dieldrin and PCBs have exceeded recommended levels in fish flesh at some places on the river.

Taste Producing Substances

Although fish mortality due to water pollution is a rare event on the river, the value of the fishery can be completely undermined by pollutants which give offensive taste to fish. Wastewaters implicated in the production of tainting substances include those from municipal wastewater treatment plants, slaughterhouses and oil refineries. Chlorophenoxy-herbicides such as 2, 4-D which are occasionally found in the river can cause tainting of fish flesh at very low concentrations (U.S. EPA, 1976).

In the flavor tests mentioned above, catfish were caged in a 440 mile section of the river during 1969. Unacceptable flavors in fish persisted one mile below Sioux City, 2.5 miles below both Omaha and Council Bluffs and 22 miles below the Kansas City metro area. Whereas the Sioux City and Omaha-Council Bluff areas were affected primarily by municipal and slaughterhouse wastes, the Kansas City area included wastewaters from an oil refinery and from chemical industries, making these latter sources suspect in tainting fish flavor in such a large segment of the river.

Power Plants, Channel Maintenance Structures, Channelization

Power plants can cause fish mortality in one of three ways: the discharge of biocides, the discharge of heated water, and the impingement of fish on the water intake screens. Good information from the Missouri River is available on the impingement of fish and on the nature of thermal discharges.

Heated water discharged from the Cooper Nuclear Plant hugs the Nebraska shore in a narrow plume and during the summer that can make more than a mile of shoreline habitat too warm for most fish. Similarly shaped but smaller plumes are typical of most other power plants on the river. During winter, fish prefer the warm waters below the discharge. Mortality can occur if the plant cuts back or stops generation and a rapid drop in water temperature occurs.

Impingement data is more difficult to interpret. Although the federal clean water law required power plants to make exact measurements of fish impingement and entrainment, there has not been a

corresponding amount of work on larval and adult fish populations throughout the river. Lately, this need has been recognized and is beginning to be addressed. Harrow (1980) made a study of larval fish populations in the main stem and selected tributaries from Gavins Point reservoir, the upper unchannelized portion of the Lower Missouri and from major tributaries such as the Platte. The channelized section of the river appears to be a relatively poor contributor of larval fish.

Few studies of adult fishes on large rivers have been able to commit enough time, expense and expertise to begin to characterize densities, community structure and age class distributions. One such study has been done on the Mississippi River in conjunction with the operation of the Rush Island power plant (Union Electric, 1979). This study provides a good example for future fish studies on the Missouri.

IMPACTS ON BIOTA NOT RELATED TO WATER QUALITY

While the preceding section has discussed how water quality has affected the aquatic biota of the Missouri, the largest impact by far on the fisheries resource of the Lower Missouri has not been caused by water pollution but by the narrowing and deepening of the entire river from Sioux City to its mouth to permit commercial navigation. Work by Funk and Robinson (1974) showed that the surface area of the river from Rulo, Nebraska to its mouth was reduced 50% by channelization. Morris (1968) extimated a 67% loss of area in the channelized section of the river bordering Nebraska. Eighty percent of the area most necessary for fish feeding, spawning, and development of juvenile fishes, the sloughs, chutes and other backwater areas were lost when the channel was narrowed (Munger, 1974).

As a result of the channelization, the diversity and the total fish population in the river have declined. Not only has loss of diversity caused large reductions in numbers of some species, but a rare species may be lost due to hybridization. Pflieger (1980) has noted a recent trend in hybridization of shovelnose and pallid sturgeon in the Missouri. This hybridization which may be the result of reduced habitat diversity and has brought the 2 species into closer association may result in the loss of pallid sturgeon in the river. A year long study by Groen and Schmulbach (1978) in 1972-73 found that catch and harvest rates in the unchannelized river above Sioux City were twice those in the channelized river and that, on a per kilometer of channel basis, the unchannelized Missouri was three times more productive in both numbers and total weight of fish. These figures are similar to those of Funk and Robinson, who compared the commercial fish catch before and after construction of most of the channelization project. They found fish catch from the Lower Missouri to be 1.3 million pounds per year in the late 1940's and only 0.4 million pounds per year during the 1970's.

SUMMARY

The Missouri has never been a productive river in terms of the growth of aquatic plants and animals. It is muddy and it has a strong current. Many algae which enter from tributaries cannot survive because the muddy water blocks the sunshine the algae require. Plants and animals adapted to living on stream bottoms can find only a few places safe from the shifting sand bottom and rapidly changing water levels. Most fish species require still water outside the main channel and such habitat has been reduced by the Corps of Engineers to a minimum on the Missouri. Rooted aquatic plants, plentiful in many rivers, are not found on the Missouri.

Water pollution can be a problem for both fish and benthic invertebrates. Small areas immediately downstream of municipal, industrial, or power discharges may be degraded and uninhabitable due to low dissolved oxygen, concentrations of toxic substances or high water temperatures. At times of runoff and high river flows, dissolved oxygen can be low throughout much of the Lower Missouri. A fish kill has been documented on one such occasion.

The most important changes to the aquatic biota have been the impoundment of the Middle Missouri which has cleared the water and increased the plankton populations, and the channelization of the river below Sioux City. The pile dikes and revetments used to narrow and deepen the channel have provided more stable substrates for benthos, but recent studies suggest the narrowed river channel may support only one-third the fish of the original channel.

CHAPTER 4
THE RELATIVE IMPORTANCE OF POINT AND NONPOINT WATER POLLUTION SOURCES

Historically, our perception of and our approach to control of water pollution on the Missouri has centered around point source discharges. Large point source discharges are more easily seen and measured than nonpoint sources. Public Law 84-660, passed in 1956, initiated widespread efforts to control point source pollution along the lower Missouri. Public law 92-500, passed 16 years later in 1972, required that nonpoint water pollution sources be identified and plans for abatement of all pollution sources be developed. Our point source efforts have resulted in either primary or secondary treatment of all point source discharges to the Missouri, and a permit system to account for the kinds and amounts of pollutants which come from these point sources. Our nonpoint efforts began around 1974 with the beginning of Section 208 planning. Compared to point source efforts, progress has been slow, reflecting our incomplete knowledge of the source and magnitude of nonpoint pollutants and the best ways to control it on a cost/benefit basis.

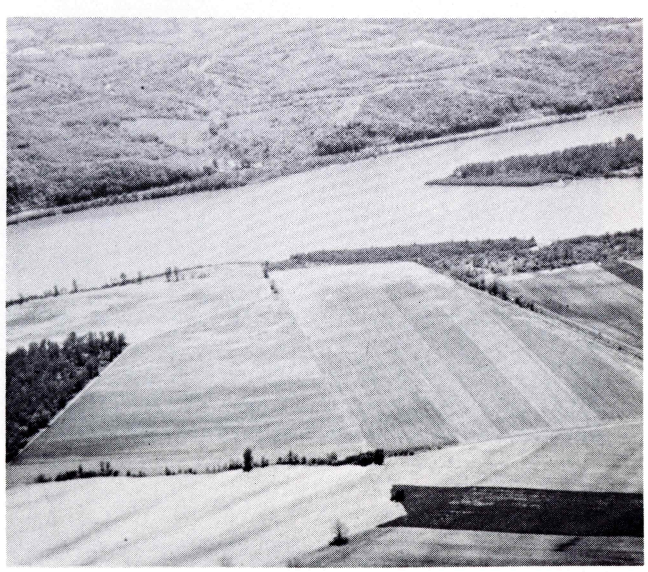
The many water quality studies performed on the Lower Missouri have given us appreciation of the severity of the separate effects of both untreated point and nonpoint water pollution sources. With this information in hand, we can no longer afford to make water quality management decisions which ignore either of these two sources of pollution. Those charged with water quality management of the Lower Missouri cannot make good decisions on point source pollution and its control without taking into account the effects of nonpoint pollution.

Based upon study results discussed earlier and three reports on the effects of large municipal discharges on large rivers, we can make some conclusions on the relative effects of point and nonpoint sources on the Missouri.

DISSOLVED OXYGEN

Sampling above and below major cities was done in the summer of 1950, well before there was any significant point source treatment on the river. The greatest effect on DO documented at that time was at Omaha, where DO dropped an average of 0.7 mg/1 and a maximum DO sag of 1.2 mg/1 was observed. At Souix City and St. Joe, average drops were only 0.1 - 0.3 mg/1 with maximum drops of 0.6 mg/1 due to municipal discharges. At the Kansas City's, the average DO was lowered 0.4 mg/1, but at times of lowest DO in the river, DO was higher just below Kansas City than above it.

Similar sampling in 1968 suggested some improvement had occurred, but sampling points were not always at the same location and the survey was conducted in October while the most valuable data from the 1950 survey was collected during the summer. The 1968 data showed an average DO sag of only 0.2 mg/1 below Omaha and no sag below Sioux City, St. Joe, or Kansas City. Sampling from 1974-1980 above and below Omaha showed an average DO sag of 0.3 mg/l. USEPA maintained sampling stations above and below Kansas City from 1973 to 1976. The results showed a 0.2 mg/l sag below Kansas City, but this was actually due to warmer water temperatures since the DO saturation values were greater below Kansas City than above it. The Metropolitan Sewer District (MSD) of St. Louis conducted an intensive study on the effects of their discharges on the Mississippi River in 1968. They found a DO sag of 1.0 mg/l occurred during the summer below St. Louis (Rains, unpublished).



The dissolved oxygen effects just mentioned occur within five to twenty miles below major discharges. Obviously, major point source discharges continue to influence dissolved oxygen levels over longer distances. Sampling in October, 1968, showed that during a period with no nonpoint sources contributing, point sources between Sioux City and St. Joe were responsible for a total drop of 0.8 mg/1*. Had the survey been during the summer, this value might have been higher.

Thus, it appears that at present, a 1.0 mg/1 DO sag would be the maximum expected from all the point sources of a major metropolitan area and possibly 1.5 mg/l as the maximum point source effect, taking into account the overlapping oxygen curves from separate cities.

By comparison, nonpoint sources can cause larger depressions in dissolved oxygen. As Figure 12 showed, the average DO value at summer water temperatures is about 6 mg/1 for most of the lower Missouri. Several studies have documented concentrations of 3.0-3.5 mg/1 can occur during rain affected flows, and when heavy widespread rains occur, DO can be even lower. Thus, nonpoint sources can cause DO sags of 2.5 to 3.0 mg/1 or more, and they do so over larger areas of the river than are affected by point sources.

BOD

Summer increases in five day biochemical oxygen demand (BOD_5) in 1950 averaged 4 mg/1 at Omaha, 1.5 mg/1 at Sioux City and Kansas City, and 0.2 mg/1 at St. Joe. Maximum increases were 6 mg/1 at Omaha, 5 mg/1 at Sioux City, 1 mg/1 at Kansas City, and 0.3 mg/1 at St. Joe.

Sampling in October, 1968, after all were receiving treatment indicated some improvement. Omaha still showed an increase of 4 mg/1, Kansas City and Sioux City an increase of 0.5 mg/1, and no increase was detectable below St. Joe. Sampling by EPA from 1973 to 1976 found no increase in BOD_5 below Kansas City. Six years of data at Omaha (1974-1979) show an average increase of 1.3 mg/1. The MSD study on the Mississippi could find no increase in BOD_5 below St. Louis.

Since in-stream BODs now range from 2 to 6 mg/1 for much of the Lower Missouri, Omaha is a significant contributor to the BOD in the river, but the other major cities are not.

SUSPENDED SEDIMENTS

Suspended sediments probably are the least compelling issue when arguments for added point source treatment are advanced. Primary treatment typically removes 60-65% of suspended solids, compared to about 90% for secondary treatment. When this increase in treatment is transferred to the Missouri River, the improvement is too small to be noticed.

Black and Veatch (1966) calculated the increase in suspended solids for primary and secondary treatment below Kansas City. The difference in the river amounted to 1 mg/1 at winter low flow conditions and 0.2 mg/1 at average flows. Since the average level of suspended sediment in the river is about 500 mg/1, the improvement due to increased point source treatment is a small fraction of one percent.

In contrast, nonpoint sources obviously exert almost complete control over the level of suspended solids in the river (except the extreme upstream segment above Sioux City). Increases in river flow invariably bring about significant increases in suspended sediment concentrations (see Figure 5, page 10).

NITROGEN AND PHOSPHORUS

Municipal waste water discharges are relatively rich in nitrogen and phosphorus compared to receiving waters. Nitrate - N and total N averaged 0.1 and 0.5 mg/1 higher, respectively, below Omaha than above it (USGS, 1974-1980). There was a 0.2 mg/1 increase in total N below Kansas City, but no change in nitrate (EPA, 1973-1976). At both Omaha and Kansas City, there was an average downstream increase in total phosphorus of 0.1 mg/1.

Sampling of many locations on the river during a two day rainfall event in 1968 showed average increases due to nonpoint sources of 0.2, 0.6, and 0.2 mg/1 respectively for nitrate - N, total N, and total phosphorus. Statistical analysis of nitrogen data collected over the last ten years shows that regression of nitrogen with such nonpoint associated variables as hydrographic peaks and discharge show strong correlation. The slope of the regression lines suggest that whenever nitrogen levels are high in the Missouri, nonpoint sources are the cause.

Reduction of nitrogen and phosphorus, regardless of source, should not be a major water quality management goal. The channelized nature of the river, with turbid, fast flowing water, is not conductive to algae blooms of nuisance proportions, and to date, the only algae problems known in the lower Missouri are caused by releases of algae from Gavins Point Dam, not from algae production in the river itself.

TWO KANSAS CITY STUDIES

Perhaps the best way to gain perspective on what water quality improvements are achievable through further investments in conventional waste water treatment is to look at the conclusions of two studies of Kansas City, Missouri, and its waste water discharges to the Missouri River (Black and Veatch, 1966, Midwest Research Institute, 1975).

***Corrected for differences in water temperature.**

Table 13 summarizes data from these two studies. Their conclusions, supported by three years of monitoring by EPA, predict very small changes in water quality due to primary treatment discharges, and even smaller further improvement associated with upgrading to secondary treatment.

Table 13
RESPONSE OF MISSOURI RIVER TO DISCHARGES OF PRIMARY AND SECONDARY TREATMENT WASTE WATERS OF KANSAS CITY, MO.

				Concentration Below K.C.	
Constituent	**Season**	**Flow (1000 cfs.)**	**Approximate Concentration Above K.C.**	**Primary**	**Primary & Secondary**
BOD_5	Winter	10-20	2	5	2.5
BOD_5	Summer	55	3	3.6[1], 4.2[2]	3.1[1], 3.3[2]
Susp. Solids	Winter	10	200	201[1] - 205[2]	200
Susp. Solids	Summer	55	700	700	700
DO	Winter	17	12[2]	11.8[2]	11.9[2]
DO	Summer	35	6.1[2], 8.4[1]	6.9[2], 7.2	——
DO	Summer	55	6.1[1]	6.2[1]	6.2[1]

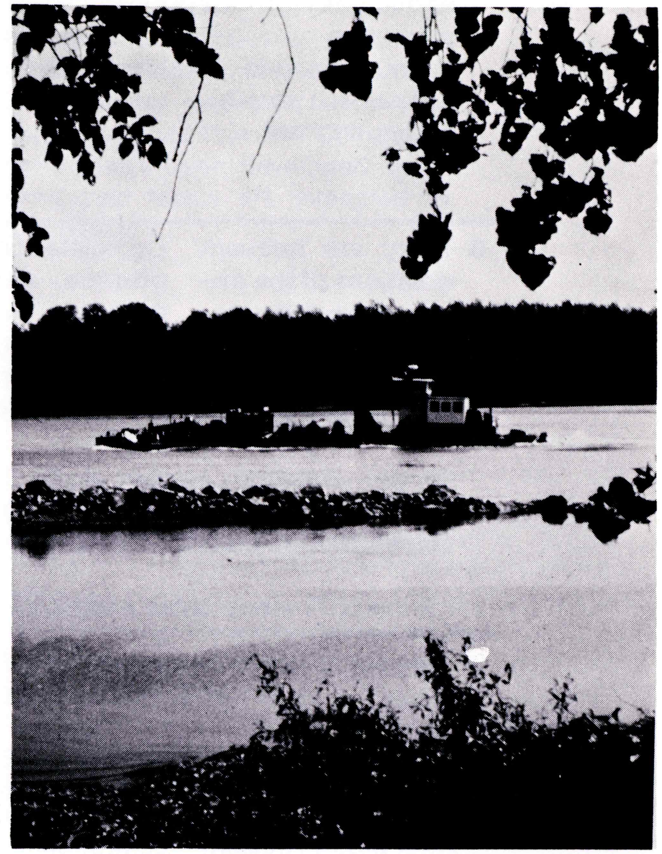
Superscript #1 denotes Black and Veatch estimates, #2 denotes MRI estimates, no superscript denotes agreement between the two studies.

CHAPTER 5
A WATER QUALITY MANAGEMENT PLAN FOR THE MISSOURI?

Water quantity, except during times of heavy rainfall and runoff, is managed on the Lower Missouri for waste assimilation, for proper functioning of water intakes and for commercial navigation.

Water quality is also managed, but not on a system-wide basis as is discharge. Water quality management on the river is shared by the states of Iowa, Nebraska, Kansas, and Missouri. These states recognize somewhat different uses and, in some cases, have different standards for the protection of those uses. For example, Nebraska and Iowa recognize the Missouri, where it borders those states, as suitable for swimming and other whole body contact recreation, but Missouri, which shares part of that segment with Nebraska, does not. Nebraska's standard for partial body contact recreation is twice as stringent as Iowa's. Nebraska and Iowa have standards for total dissolved solids, but not sulfates, In Kansas and Missouri, the situation is reversed.

These have been more "management problems on paper" than real hinderances to managing water quality, but the state by state approach has had its problems. Some major municipal discharges to the river have been placed high on state priority lists for construction grants funding and now have secondary treatment, while other discharges in other states were low on state priority lists and still have only primary treatment. A second problem is the lack of a consistent disinfection policy. At present, Iowa is disinfecting both major waste water discharges, Nebraska is disinfecting three of five major waste water discharges while Kansas and Missouri are not disinfecting any discharges in the river. A third problem, obvious from the discussion on water quality in Chapter 2, is that a comprehensive, system wide monitoring plan is lacking. Water companies have the longest period of record, but most analyze water for a limited number of constituents and quality assurance in laboratory work can vary greatly from lab to lab. The USGS monitors the river monthly, at several locations for a wide variety of constituents, and should provide a consistent level of quality assurance.



Unfortunately, they have only ten years of record at Hermann and St. Joseph, Missouri, eight years at Sioux City, six years at Decatur, Nebraska, and only one year at Omaha. Other agencies, such as USEPA and various state agencies also monitor the river, contributing to the total information base, but with varying levels of quality assurance. Thus, they also contribute to the difficulty in interpreting that information base.

Table 14 presents an outline of major points that should be addressed in developing water quality management plan for the Lower Missouri River, based upon known problems and information needs.

Table 14
WATER QUALITY MANAGEMENT PLAN FOR THE LOWER MISSOURI RIVER

Present and Anticipated Problems	Management Objective	Recommended Actions
1. High level of bacterial contamination in water withdrawn for drinking water.	Maintain the Missouri as a safe drinking water supply.	Continue disinfection at water treatment plants.
2. Bacterial standards for whole body and partial body contact recreation are frequently violated in states which have this designated use.	Complete compliance with bacterial standards for uses identified.	Review the status of whole body and partial body contact recreation as beneficial uses of the river. Review the standards for these two uses. Wastewater disinfection as required to meet standards.
3. There are frequent violations of the dissolved oxygen standard during rain affected flows during summer and autumn.	Complete compliance with dissolved oxygen standard for protection of aquatic life.	Determine which components of rain-affected flows are major contributors of oxygen-demanding materials; urban runoff, rural runoff, combined sewer overflows, underdesigned waste retention structures (such as at animal confinement areas). Develop a dissolved oxygen model for the Lower Missouri. Review D.O. standard (ie. the ability of the resident aquatic community to withstand intermittant periods of substandard D.O.) Direct management efforts toward most important sources.
4. Future uses of Mo. River water in western coal development and for irrigation may cause violation of the sulfate standard.	Keep the concentration of sulfates in the Lower Missouri at 250 mg/1 or less.	All affected states should participate in interstate water resources project planning With the demise of the MRBC, states sharing an important aquatic resource, such as the Lower Missouri, should find a forum for discussion of interstate water quality issues.
5. Mercury, copper, zinc, cadmium, and lead have exceeded standard for protection of A.L.; cadmium, and lead have exceeded the primary (health standard for drinking water supply.	Achieve complete compliance with water quality standards.	Determine major sources of these metals (ie. point, urban nonpoint, combined sewer overflow, rural nonpoint). Direct management efforts towards most important sources.

Table 14 (continued from preceding page)

6. Iron and manganese have exceeded secondary (aesthetic) standard for drinking water supply.	Achieve complete compliance with water quality standards.	Determine major sources of these metals (i.e. point, urban nonpoint, combined sewer overflow, rural nonpoint). Direct management efforts towards most important sources.
7. Dieldrin and DDT concentrations have exceeded the standard for protection of A.L. 8. Dieldrin and PCB content of some fish exceed FDA standards for interstate shipment.	Achieve complete compliance with standards.	Annual monitoring of fish flesh (since the legal uses of these and other chlorinated hydrocarbons have been greatly restricted , and less expensive methods of PCB degradation have been developed, environmental levels are expected to diminish).
9. We have not yet documented the potential toxicity problems due to chloramines and/or total residual chlorine.	Achieve complete compliance with standards.	Monitor river immediately below chlorinated discharges for TRC. If levels exceed standards, use of diffuser pipes or other methods of rapid dilution should be considered. All actions listed under Problem 2.
10. We have not yet characterized frequencies and concentrations of toxic substances in the river.	Development of standards for protection of drinking water supply from long term chronic toxicity. Achieve complete compliance with standards.	Determine present levels of the pollutants in the river. Same actions as for Problems 5 and 6.
11. Monitoring of water quality by many entities with varying levels of laboratory quality assurance makes for an inaccurate and confusing data base.	Obtain accurate information on water quality of the river.	Concentrate as much monitoring as possible within as few entities as possible through cooperative agreements. Maintain good quality assurance programs for all entities doing analytical work on the river.

PRESENT ACTIONS

Many of the recommended actions have already been fully or partially addressed. These include:

- *Continued Disinfection at Water Treatment Plants.* At present, most water treatment plants chlorinate heavily. Levels of chlorine typically used are lethal to viral as well as bacterial organisms, but the combination of free chlorine and organic materials in the water can cause the formation of toxic compounds called trihalomethanes. Some water companies on the Missouri are now using "combined" forms of chlorine, rather than free chlorine, to avoid the formation of trihalomethanes. Combined chlorine requires a longer contact time to kill bacteria.
- *Review the Status of Whole Body and Partial Body Contact Recreation on the Lower Missouri. Review the Standards for These Two Uses. Review the Dissolved Oxygen Standard.* All states, as part of their responsibilities under the Clean Water Law, review every three years the beneficial uses of water and the quality standards needed to protect those uses.
- *Determine Which Components of Rain-Affected Flows are Major Contributors of Toxic Heavy Metals.* This effort is occuring, but in piecemeal fashion. We have good information on major point sources and during the past few years there has been emphasis on nonpoint urban runoff. The original concept of section 208 planning, a section of the Federal Clean Water Law, was to develop a water pollution control plan based upon knowledge and treatment of all pollution sources. Whether or not 208 continues as a viable federal activity, the states should continue to increase their knowledge of nonpoint source pollution and to develop a plan for controlling oxygen demanding wastes during periods of heavy rainfall and runoff.
- *The States Should Find a Forum For Discussion of Interstate Water Quality Issues.* The Association of State Water Pollution Control Administrators (ASIWPCA) is an active association which could function in this capacity. Several members of the federal MRBC are attempting to replace it with an interstate, non-federal, association.
- *Determine Which Treatment Methods are Most Effective For Reduction of Toxic Heavy Metals and Organic Pollutants.* Work has begun in the past few years to compare removal rates of these pollutants by conventional treatment and by pretreatment. The State of Missouri and the cities of St. Louis and Kansas City were working together on a report which addresses this issue.
- *Monitoring of the River for Dieldrin, PCBs and Other Contaminants of Fish Flesh, and Monitoring of the Water For Toxic Pollutants Which May Endanger Drinking Water Supplies.* A small amount of work has been done. Routine analysis of fish flesh on an annual basis was initiated by the State of Missouri in 1980, but is not yet a part of other states monitoring plans.

Monitoring for toxic substances is increasing. The Missouri River Public Water Supplies

Association, which has member water companies in all four states from Omaha-Council Bluffs to St. Louis, is initiating a network of six stations with daily monitoring for 27 of the most common toxic organic compounds. The State of Missouri is entering into an agreement with the association to do occasional monitoring for an expanded list of 116 toxic pollutants. USEPA plans to monitor for all 129 "priority pollutants" in the Kansas City area.

NEEDED ACTIVITIES AND PROGRAMS

There are at least three areas where productive work in water quality management on the Lower Missouri still is required.

- A Comprehensive Nonpoint Pollution Control Program. The greatest water quality problems are caused by rain affected flows. A comprehensive approach, as envisioned by the Federal Clean Water Law under Section 208 will be necessary to manage nonpoint sources.
- Due to the complexity of urban wastewaters, particularly in large cities, we need to make careful appraisal of the kinds of industries and wastes present and whether there may be better ways to treat wastes than by conventional means.
- We need basic research on the toxicity of a wide variety of chemicals so that proper standards for the protection of drinking water supplies can be established.

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